Air Pollution and the Automobile

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Environment Conservation in Ontario

Department of Energy and Resources Management

Hon. George A. Kerr, Q.C., Minister J.C. Thatcher, Deputy Minister

AIR POLLUTION AND THE AUTOMOBILE

by

John G. Jefferies
Chief, Automotive Emission Control Section
Air Management Branch

Automobile exhaust can be dangerous and is a major source of air pollution. In addition to carbon dioxide and water vapour, it contains carbon monoxide, oxides of nitrogen, unburned hydrocarbons and lead.

Carbon monoxide concentrated in an enclosed space can be lethal. Less dangerous but still harmful amounts can build up in conditions of heavy traffic or from faulty exhaust systems.

Oxides of nitrogen and hydrocarbons react under the influence of sunlight to produce photochemical oxidants -- compounds that make the eyes smart and irritate throat and breathing passages. Lead from gasoline added to other sources of lead in the atmosphere is of growing concern to health authorities.

Causes of Automotive Pollution

Automotive pollutants result from the incomplete burning of fuel. When there is sufficient oxygen, hydrocarbon fuel is completely converted into carbon dioxide and water vapor. Incomplete combustion also produces carbon monoxide, hydrocarbons and oxides of nitrogen.

Incomplete combustion can occur for various reasons -- poor mixing of air and fuel, short combustion time, quenching of the combustion process near a cool chamber wall, dead space where the combustion flame can not pentrate.

Some of these problems can be eliminated by heating the air or fuel prior to mixing, or replacing the standard carburetor with a fuel injection system.

Crankcase emissions are eliminated by using a PCV (positive crankcase ventilation) valve that feeds crankcase vapors back to the air intake system to be burned in the combustion chamber.

Gasoline evaporating through either the fuel tank breather tube or carburetor is another source of automotive pollution. It can be greatly reduced by terminating such tubes and other outlets with an activated charcoal filter that absorbs escaping vapors.

Controlling Automotive Pollution in Ontario

To reduce pollution from automobiles in Ontario, regulations have been made under the Air Pollution Control Act, 1967. The first regulations went into effect at the beginning of the 1969-model year. They called for special devices to prevent emission of crankcase and blow-by gases into the atmosphere and control over exhaust emissions.

Test methods have been refined under legislation which has become more stringent each year. Initial legislation reduced pollution from automobiles by 50 per cent. By 1972, pollutants will have been cut by a further 30 per cent. By 1975, emissions from new cars will be only 5 to 10 per cent of 1968 emission levels.

Heavy duty gasoline and diesel powered vehicles have also been covered by regulations since the beginning of 1970. The Automotive Emission Control Section is working closely with the Automotive Transport Association of Ontario in an attempt to reduce excessive emissions from diesel trucks and buses. It is also conducting research into the adoption of anti-pollution devices for older uncontrolled motor vehicles.

The Air Management Branch operates two mobile test laboratories to carry out spot checks on 1969 and newer model cars. These checks indicate whether a pollution control device is functioning efficiently or has been tampered with or removed. Maximum fine for tampering or removal is $100.00.

Exhaust Control Methods

There are four basic ways of controlling automotive exhausts.

1. Controlled combustion systems involve fine tuning of the carburetor and timing mechanism to produce more efficient combustion and, therefore, lower concentrations of pollutants.

Engines equipped with control combustion systems have leaner mixtures strength, usually a ratio of approximately 14:1. The spark timing is advanced or retarded for better combustion depending on the particular mode of vehicle operation. Some of the exhaust gas is also recycled through the engine for better combustion.

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Engine Control Methods

There are four basic ways of controlling automotive emissions,

1. Modified combustion systems involve fine tuning of the carburetor and timing mechanisms to provide more efficient combustion and, therefore, lower concentrations of pollutants.

Modern engines with engine modification systems have leaner carburetor settings, usually a ratio of approximately 16:1. The spark timing is advanced or retarded for better combustion depending on the particular mode of engine operation. Some of the exhaust gas is also recycled through the engine for better combustion.

2. The air injection method uses an air pump to force air into the exhaust manifold of the car engine. The temperature of the air-exhaust gas mixture is high enough to allow combustion to occur. As a result, most of the polluting gases are burnt to carbon dioxide and water vapor.

3. The fuel injection method accurately meters a fixed amount of fuel and air to each combustion chamber of the vehicle's engine. Better combustion can be achieved with this approach than with the carburetor system. Fuel injection cuts off the fuel supply completely during deceleration, a time when a carburetor causes high pollutant output.

4. A catalytic muffler containing certain types of catalysts can be used to oxidize toxic gases in the exhaust. Due to the poisoning effect that lead has on the catalyst, however, the system can only be used with gaseous fuels, diesel fuel or unleaded gasoline.

In the past few years there have been a number of encouraging developments in the area of automotive pollution control. A large public utility has tested dual-fuel vehicles. These cars use gasoline on the open highway and either propane or natural gas in congested areas and stop-and-go traffic.

Tests have suggested that car engines using natural gas or propane can operate for considerably greater mileages between maintenance checks than those using gasoline. This is due to an absence of both spark plug fouling and engine oil dilution.

Low-Lead and Lead-Free Gasolines

The use of lead-free and low-lead gasoline in existing vehicles is not expected to reduce emissions of the main gaseous pollutants -- carbon monoxide and hydrocarbons -- although a number of conflicting reports have been issued on this topic.

Some reports state that the use of lead-free fuel increases the emission of hydrocarbons, particularly those with high, photochemical smog-forming potential. Other reports indicate that the use of such fuel will bring about a decrease in hydrocarbon emissions. On this latter point, however, there is additional conflict as to whether fuel can be low-lead or whether it must be completely lead-free before hydrocarbon emissions are reduced.

Vehicles can be split into three groups in reference to their use of lead-free gasoline.

1. Pre-1970, North American vehicles. Those that have been operated for a considerable period of time on leaded gasoline possess a protective layer of lead on various engine parts. A switch to unleaded fuel should produce no adverse effects.

2. North American vehicles sold late in the 1970 model year plus 1971 and later Asian and European imports will not be adapted to operate on unleaded fuel. Use of this type of fuel from the very beginning of engine operation could give rise to severe engine malfunction. A possible solution is to operate such vehicles for a few hundred miles on leaded fuel, followed by general use of unleaded gasoline. It will probably be necessary to repeat the use of leaded gasoline at intervals to ensure a replacement of the protective lead coating.

3. 1971-model North American vehicles have for the most part been manufactured for satisfactory operation on 91 octane, lead-free gasoline. Use of this fuel poses no problems.

The use of lead-free gasoline will help reduce the total amount of lead being emitted into the atmosphere. It has been introduced in anticipation of a proposed United States ban on the use of lead in gasolines.

In addition, lead-free gasolines are necessary for the satisfactory operation of the catalytic muffler -- the only control device available that will enable compliance with exhaust emission standards proposed for 1975. General Motors has already stated that it intends to install catalytic mufflers on some of its 1973 cars and on all of its cars from 1975 onwards.

Alternatives to the Internal Combustion Engine

Possible alternatives to the internal combustion engine are an electric power source, a modified steam engine and the gas turbine.

The totally electric car is not considered a practical proposition at present. It is of necessity small because of low power availability. In addition, the considerable weight of the power source (rows of batteries) and the volume it occupies leaves both very little power and room for transportation of goods, luggage, etc.

The electric car has a top speed of about 50 m.p.h. and a small range (about 40 miles at 50 m.p.h. and 65 miles at 30 m.p.h.). As a result, it is limited to urban driving. Battery recharging time is considerable.

Possessing definite potential is the gasoline-electric hybrid. Several types have been produced on an experimental basis. Electric power is used for urban driving during which low maximum speed is not a great disadvantage. At the same time the high pollution levels created by gasoline powered vehicles while idling or travelling at low speeds are eliminated.

Outside urban areas, when high speeds are necessary, the hybrid is switched over to gasoline. Emissions from gasoline engines are much lower at high speeds. Part of the power generated is used to recharge the batteries.

The steam or Rankine engine works on the same principle as the regular steam engine. Recently developed propulsion systems cannot really be termed "steam," however, because the water component has been replaced by various low boiling point, organic compounds of the type used in refrigerators (freon etc.).

This engine burns fuel very efficiently producing only 1% of the emissions of a gasoline engine. Speeds are comparable with those of conventional vehicles. As an external combustion engines, it can burn any fuel. Kerosene is generally used.

Much development work was done on this engine several years ago. Many difficulties persisted, however, and not all of them have been resolved. This approach has lost much of the promise that it once held out as a possible pollution-free alternative to the internal combustion engine.

The gas turbine has been tested several times as a propulsion unit for the automobile. Difficulties include noise, slow acceleration, vehicle vibration and engine weight and size. Pollutant output is considerably less than that resulting from a gasoline engine and still somewhat less than that from a diesel engine. Concentration figures for exhaust components cannot be meaningfully compared, however, due to dilution of gas turbine exhaust with large quantities of excess air.

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Oxides of nitrogen and hydrocarbons react under the influence of sunlight to produce photochemical oxidants -- compounds that make the eyes smart and irritate throat and breathing passages. Lead from gasoline added to other sources of lead in the atmosphere is of growing concern to health authorities. The latest medical opinion is that present lead levels do not constitute a health hazard. However, there is evidence that the lead level is rising, particularly on the surface of the ground. Lead could therefore eventually become a problem if left unchecked.

Causes of Automotive Pollution

Automotive pollutants result from incomplete burning of fuel. When there is sufficient oxygen, hydrocarbon fuel is completely converted into carbon dioxide and water vapor. Incomplete combustion also produces carbon monoxide, hydrocarbons and oxides of nitrogen.

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Some of these problems can be eliminated by heating the air or fuel prior to mixing, or replacing the standard carburetor with a fuel injection system.

Crankcase emissions are eliminated by using a PCV (positive crankcase ventilation) valve that feeds crankcase vapors back to the air intake system to be burned in the combustion chamber.

When a car is stationary, particularly when its engine is hot, gasoline can evaporate through either the fuel tank breather tube or carburetor, becoming another source of automotive pollution. It can be greatly reduced by terminating such tubes and other outlets with an activated charcoal filter that absorbs escaping vapors. When the car engine is started, air is sucked through the charcoal filter, extracting the fuel vapors. The mixture then passes through the air filter into the engine, where it is burned.

Controlling Automotive Pollution

Since January 1, 1971 the control of air pollution from motor vehicles has been a shared federal-provincial responsibility. The federal government now establishes all emission standards and enforces them at the manufacturing level. Provincial governments are responsible for the control of pollution emissions from vehicles after they have been sold.

Prior to 1971 regulations controlling automotive pollution existed only at the provincial level. Ontario, in fact, was the first province to pass legislation in this area. Its initial regulations reduced pollution from 1969 model cars to 50 per cent of that produced by uncontrolled 1968 model cars. Subsequent regulations for 1970 and 1971 reduced emissions further.

Federal regulations for the 1972 model year have reduced car emissions to 20 per cent of the 1968 level. It is anticipated that this figure will be down to somewhere between five and ten per cent by 1975.

In Ontario the provincial agency responsible for the control and prevention of air pollution is the Air Management Branch of the Department of the Environment. The control of pollution from motor vehicles is the special responsibility of the branch's Automotive Emission Control Section.

This section works in several ways to lessen automotive pollution. It conducts research (e.g. into the possibility of adopting anti-pollution devices for pre-1969 uncontrolled cars); maintains liaison with various motor vehicle organizations (e.g. the Automotive Transport Association of Ontario with which it is attempting to reduce excessive emissions from diesel trucks and buses); operates two mobile test laboratories to carry out spot checks on 1969 and newer model cars.

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2. The air injection method uses an air pump to force air into the exhaust manifold of the car engine. The temperature of the air-exhaust gas mixture is high enough to allow combustion to occur. As a result, most of the polluting gases are burnt to carbon dioxide and water vapor.

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4. A catalytic muffler containing certain types of catalysts can be used to oxidize toxic gases in the exhaust. Due to the

poisoning effect that lead has on the catalyst, however, the system can only be used with gaseous fuels, diesel fuel or unleaded gasoline.

In the past few years there have been a number of encouraging developments in the area of automotive pollution control. A large public utility has tested dual-fuel vehicles. These cars use gasoline on the open highway and either propane or natural gas in congested areas and stop-and-go traffic.

Tests have suggested that car engines using natural gas or propane can operate for considerably greater mileages between maintenance checks than those using gasoline. This is due to an absence of both spark plug fouling and engine oil dilution. However, due to problems of distribution, this type of system is only likely to be of benefit to fleet operators whose vehicles return each night to a central refuelling point. It is unlikely to become the everyday fuel for the average motorist.

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fuel can be low-lead or must be completely lead-free before hydrocarbon emissions are reduced.

Vehicles can be split into three groups in reference to their ability to use lead-free gasoline. In the following cases, it is assumed that a lead-free gasoline of sufficiently high octane number is available to satisfy the octane requirement of an engine as a result of its compression ratio.

1. Pre-1970 North American vehicles which have been operated for a considerable period of time on leaded gasoline possess a protective layer of lead on various engine parts. A switch to unleaded fuel should produce no adverse effects.

2. North American vehicles sold late in the 1970 model year plus 1971 and later Asian and European imports will not be adapted to operate on unleaded fuel. Use of this type of fuel from the very beginning of engine operation could give rise to severe engine malfunction. A possible solution is to operate such vehicles for a few hundred miles on leaded fuel, followed by general use of unleaded gasoline. It will probably be necessary to repeat the use of leaded gasoline at intervals to ensure a replacement of the protective lead coating.

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This engine burns fuel very efficiently, producing only 1 per cent of the emissions of a gasoline engine. Speeds are comparable with those of conventional vehicles. As an external combustion engine it can burn any fuel. Kerosene is generally used.

Much development work was done on this engine several years ago. Many difficulties persisted, however, and not all of them have been resolved. This approach has lost much of the promise that it once held out as a possible pollution-free alternative to the internal combustion engine.

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A Conservationist Looks at Pollution

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"We travel together, passengers on a little space ship, dependent on its vulnerable supplies of air, water and soil --- preserved from annihilation only by the care, the work, and I will say, the love we give our fragile craft." Adlai Stevenson.

Foreword

So you're interested in pollution.

We, in the Conservation Authority, are glad to hear it. We know that an informed public is vitally important in the fight for an improved environment. Always remember that governments can proceed only as fast as the people will allow; for this reason it is up to all of us to spread accurate, factual information.

One word of caution: constantly bear in mind that the subject of pollution is very complicated and very technical. For this reason, in even the best treatment of the subject on a concise scale, there is a danger of over-simplification. It is far from a simple matter, and will really require much extra reading on your part. But, if you promise to remember this risk, we will try to put down some basic facts to help in your search for information.

A CONSERVATIONIST LOOKS AT POLLUTION

by

J.A. Nornabell, Chairman Otonabee Region Conservation Authority
Dr. R.L. Edwards, former Chairman, Department of Biology, Trent University
J.G. Hooper, Chairman Ontario Branch, Canadian Institute of Pollution Control

What do you mean by pollution? The Oxford Concise Dictionary says "to pollute is to destroy the purity of; make (water, etc.) foul or filthy.' Sounds simple enough, but, curiously, pollution means different things to different individuals, even different things to the same person in different circumstances.

For example, distilled water is surely the purest form of water; yet from the standpoint of a fisherman, a lake filled with distilled water would be 'polluted' because no fish could grow in it. Sea water has salt in it, and the sea fish flourish in it. Yet for many purposes, (drinking, use in engines, or as a medium for fresh-water fish), it is polluted.

Pollution is usually associated with man and his various activities; but nature herself causes it too. When leaves etc., fall from trees that overhang bodies of water, organic pollution takes place. Where marshes exist, large numbers of bacteria enter the watercourse as a result of decay of the weeds and reeds. This natural decay may cause high "coliform counts", which may be wrongly interpreted as indicating dangerous pollution.

The accepted level of coliform count in water to be used for swimming is up to 2,400 per 100 millilitres, and this level can easily

be exceeded near decaying vegetation. Nature usually can look after her own pollution and can cleanse the waters through the action of sunlight, micro-organisms, (minute forms of life, plant and animal,) and cascades or white-water areas in the rivers.

It is only when man overloads her efficient purifying mechanism that trouble occurs and we face situations which may be unsightly, unpleasant and even dangerous to health. It is also well to remember that, as the number of humans increase on earth, and their intellectual and technological ability grows, the possibilities of this abuse of nature's mechanism becomes more probable.

The pollution of Adlai Stevenson's "fragile craft" can be divided into three general areas, though each in actuality overlaps the others: air, water and soil. For our present purposes, we will limit our discussion to water and perhaps pursue the others later. Again, for our purposes, we will concentrate on fresh water, and even more, limit it to a large extent to surface water (e.g. lakes, rivers, creeks, swamps, etc.).

Bear in mind though, that about forty per cent of Ontario's population take their drinking water from ground water that comes from wells, dug, drilled or flowing artesian. When pollution of this source occurs it is very serious indeed, since the correction of it is all but impossible. It is for this reason that sanitary land-fill methods of garbage-disposal are now being watched so closely. Organic matter in this garbage decays or ferments and percolates down to the underground river which carries the ground water, called the "aquifer".

Pollution sources of fresh surface water may then be divided into three main categories:

(1) domestic

(2) industrial

(3) agricultural

The first and second may be carried to the treatment works by sanitary sewers. On the other hand, storm sewers pick up the run-off from the streets, may by-pass the treatment plant, and run directly to the natural waters. Occasionally, drains lead directly to the watercourse from the offending source. This is rapidly being corrected.

The third pollution source is agricultural wastes. These are washed from the surface of the land by sheet erosion in spring, or in a heavy downpour in seasons when the ground is bare, or they percolate through the soil to end in the watercourses, or are carried by tiles, drains and ditches to them.

All three types of pollutants can be subdivided into two headings: organic or inorganic wastes. Organic wastes are capable of being broken down into carbon, oxygen and hydrogen by treatment or by natural agents, such as sunlight or oxygen which is dissolved in clean water, and thus are totally changed. Inorganic wastes contain minerals and chemicals: salt, sand, phosphates, nitrates, mercury, chrome, etc. The situation is not as simple as this sounds, because in all three forms of waste both organic and inorganic matter is often present.

High on the list of organic pollutants is the material associated with bacteriological pollution: the fecal or natural body wastes from

man and animals. When water contains a high fecal bacteria count, It suggests that disease-carrying organisms may also be present. That is why a high E. coli count, though of itself not necessarily dangerous, indicates possible trouble from intestinal bacteria which may be there and which do carry disease. (Infectious hepatitis, diarrhea, dysentery, typhoid, etc.,). Water is classed as "good" with an E. coli count of up to 50 per 100 millilitres.

Bacterial pollution may come from inadequate sewage treatment plants, from unsatisfactory septic tanks, (either operating poorly, or badly situated and drained), or from drainage from farm operations, barnyards, etc. For years the scientist in the laboratory has been able to control this type of pollution with proper sewage plants and chlorine. But inadequate cottage or resort systems, municipalities which dragged their feet about installing sewage systems, and now the new method of raising animals, (hogs, chickens and cattle) in what can only be called animal factories raise problems which must be solved.

Sanitary and Storm Sewers

Sanitary sewers are a system of pipes that carry to the sewage or wastewater treatment plant domestic wastes from toilets, sinks, tubs, and basins; commercial wastes from food-handling and processing; and industrial wastes from factories, etc. The large trunk sewer which collects the flow from the individual establishments is usually located under the centre of the roadway with man-holes to the surface every 250-300 feet.

Storm sewers collect run-off from streets and parking-lots, and from weeping tile and roof drains around buildings and uncontaminated

industrial processing waters. The metal gratings at the road-gutters are the inlets to them. Since it is considered that this run-off is primarily rainwater or melting snow, these usually run directly to the watercourse.

At a very few places, however, the sanitary sewers cross-connect with the storm sewers. The main purpose of this 'legal' cross-connection is to provide a safety-valve or overflow for emergency conditions. Such abnormal conditions may result from a blockage in the main sewer or extreme overloading because of intense rainfall. Under such conditions, it is considered preferable to have a weak dilution of sewage diverted with water to the watercourse which has some properties for self-purification or recovery, than to have the same material backing up into basements in the affected area.

Overflow or by-pass facilities are usually provided at treatment plants as relief in case of a long term power or equipment failure or excessive overloading. The use of such facilities is rare indeed, and is usually of short duration. If it does occur, it is during storms or in other conditions when the riverflows are too high, thus considerable dilution takes place.

It should be kept in mind that high flows in the sewers to the treatment plant do not result in an overflow of any amount beyond 'normal' . What happens is that the sewage passes through the plant slightly more quickly and the treatment process (biological and chemical) does not have quite as long to operate. This means that all sewage gets less treatment than normal, rather than some getting the usual treatment and the remainder none. Since this occurs only when there is an extra high flow of water, there will then be more natural dilution.

In the Peterborough system for example, there is no place where the reverse process of storm sewers overflowing into sanitary sewers occurs. If this were to happen, it would increase the hydraulic load on the sewers or the treatment plant. There is the exception of illicit connections of roof leaders, the legal but sometimes excessive contributions from foundation drains (e.g., from new, unsettled house foundation backfilling) or of sometimes excess surface water entering via sanitary manhole tops.

Industrial waste from our factories and plants is a much more complicated question, involving many sophisticated elements, which were not dreamed of when the original plant was built. In some cases the treatment plant can remove these pollutants, in others it can't. In any case it is sometimes more reasonable to handle and treat the industrial wastes in a combined form at the central plant, while at other times separate pre-treatment at the source is preferred.

In Peterborough joint treatment is the most common. The classic case of an element that can't be removed easily from waste-water is phosphorous, present in the form of phosphates. Phosphorous comes from domestic wastes, including detergents, and from agricultural operations. Tertiary treatment, or three-stage plants are being developed that take it out, but since most municipalities still have only primary (one-stage) treatment facilities, and full-scale operating plants are almost non-existent, this makes our goal very unlikely for some time. Sewage lagoons, or as they are now more delicately called, waste stabilization ponds, are believed to be more efficient in removing phosphorous and its salts.

Why do we worry about phosphorous particularly? Because it is one of the foods, or nutrients, as they are called, required for the growth of algae. It is in other words, an excellent plant fertilizer.

Algae are the plant micro-organisms at the base of the food chain: the little fish feed on them, the bigger fish feed on the little ones, and man feeds on the big fish. If there were no algae there would be no fish.

Trouble looms when there is too much phosphorous in the water. If circumstances are conducive an overbloom of algae results. These little organisms wash up on shore, and in the process of decaying, use up the oxygen which is dissolved in the water, making the water useless for other forms of life. During decay the algae are ugly, smelly and actually can be dangerous as they may be poisonous. It is ironic that fertilizers that make things grow can cause the 'death' of a water body. This comes of course from an over-growth of plant-life.

Phosphorous in the form of phosphates comes from four main sources:

(1) excrement in domestic wastes

(2) detergents which contain it 'to make clothes whiter'

(3) ground surface run-off from urban areas

(4) the run-off in spring from farmers' fields which have been fertilized.

This latter source is relatively unimportant in most areas because phosphorous does not travel through the soil like nitrates,

(does not leach out), and can only reach the watercourse when sheet erosion occurs - the washing off and away of the soil itself which has the fertilizer in it. A good farmer does not allow this to happen because he is losing his valuable topsoil also in the process.

Some lakes and rivers, because of their nature, are always going to be rich in phosphorous. If a lake is relatively shallow or if it has a high proportion of natural vegetation either contained in it or falling into it, it will usually receive more phosphorous than seems desirable. Such lakes are our Kawarthas. For this reason, it is doubly important for us to ensure that any artificial additions are removed, as those from improperly treated sewage, detergents, or farms.

There is little industrial pollution entering our system of lakes. The greatest danger to them comes from bacterial and nutrient pollutants. It is therefore up to us to assist our Department of Health, the Ontario Water Resources Commission, and the City Engineer in the campaign to improve the sewage disposal systems for the municipalities, cottages and resorts of our area. This will cost you money, and you must do without some luxuries to achieve it, but it is the duty of all of us, as responsible citizens to make this personal sacrifice in order to preserve our natural resources.

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How Air Pollution Affects Vegetation

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Environment Conservation in Ontario

Department of Energy and Resources Management

Hon. George A. Kerr, Q.C., Minister J.C. Thatcher, Deputy Minister

HOW AIR POLLUTION AFFECTS VEGETATION

by

Dr. Samuel N. Linzon
Chief, Phytotoxicology Section
Air Management Branch

Air pollution affects the environment in various ways. It can injure vegetation, endanger human and animal health, soil buildings and clothing, contribute to highway and air travel accidents by reducing visibility, help depress property values and generally interfere with our aesthetic enjoyment of the landscape.

Vegetation injury due to air pollution is an area of particularly serious concern. It can range from visible markings on foliage to reduced growth and yield to premature death of plant life. The ensuing visual and ecomonic consequences can at times be disastrous. Injury to crops possessing marketable foliage such as lettuce or tobacco can result in especially high losses.

Investigation of Vegetation Damage in Ontario

The Air Management Branch of the Department of Energy and Resources Management is responsible for the control and prevention of air pollution in Ontario. The Branch consists of six sections -- Abatement, Approvals and Criteria, Automotive Emissions Control, Meteorology and Air Quality, Chemical Laboratory, and Phytotoxicology.

The Phytotoxicology Section is responsible for determining the degree and extent of air pollution injury to all types of vegetation throughout Ontario. (Any pollutant that injures vegetation is a phytotoxicant.) The section pursues its objectives by:

1. Investigating complaints concerning suspected air pollution injury to all types of vegetation -- forests, orchards, farm crops, ornamental plantings -- in both rural and urban areas. In so doing it is necessary to differentiate pollution injury from similar injuries caused by insects, disease, adverse weather, poor nutrition or mismanagement.

2. Conducting surveillance studies in areas of concern where adverse effects on vegetation may occur as a result of emissions from existing or future sources of air pollution. If ambient air quality records coupled with vegetation data indicate the biological component of the environment to be in danger, then prompt abatement action is taken.

3. Carrying out practical research studies in controlled environment chambers on the effects of air pollutants on vegetation. These studies are conducted to complement field investigations, screen resistant plant species and determine air quality criteria for the protection of agriculture and forestry.

The staff of the Phytotoxicology Section consists of plant pathologists, agricultural specialists, a plant ecologist, a biostatistician, and greenhouse and laboratory technicians. The Phytotoxicology laboratory and main offices are in Toronto. A northern regional office is located in Sudbury.

In the Phytotoxicology laboratory, vegetation samples collected during complaint or surveillance visits are examined by pathological and histological techniques, and processed for chemical analyses. A herbarium is maintained to demonstrate, compare, and diagnose plant material damaged by particular air pollutants.

Phytotoxicology personnel investigated 57 air pollution complaints in 1968, 76 in 1969 and 139 in 1970. Vegetation suspected of being injured by air pollutants included ornamental flowers, garden fruits and vegetables, stored vegetables, greenhouse chrysanthemums and roses, farm crops (white beans, tomatoes, green onions, winter wheat, oats, and corn), animal pastures and cured hay, and fruit and forest trees.

Suspected air pollutants and those ascertained as causing vegetation injury included fluorides, sulphur dioxide, oxidants, boron, lead, chlorine, hydrogen chloride, liquefied gases, chromium, nickel, salt spray, urea, nitrogen dioxide, ammonia, cement dust, magnesium-lime dust, flyash and detergents.

The Phytotoxicology Section maintains a close surveillance of vegetation in areas of concern throughout Ontario. Baseline studies are conducted in agricultural or forested areas before a major pollution source becomes operational to determine the pre-pollution endemic conditions. Ecological studies keep the Section informed of increasing or decreasing vegetation effects in the vicinity of pollution sources.

Ecological studies consist of surveys of indigenous vegetation for the presence of chemical, insect, disease and physiological injuries; the examination of established plots for the effects of air pollution on condition, growth, yield and survival of vegetation; and the sampling and laboratory analysis of collected vegetation, soil and pond water. Instruments are maintained in study areas, to record ambient air data which can be correlated with vegetation effects.

The number of surveillance visits to areas of concern increased from 41 in 1969 to 96 in 1970. The number of samples taken increased from 1714 in 1969 to 3344 in 1970.

Effects of Air Pollutants on Plants

Air Pollution injury to plants can be evident in various ways. Injury to foliage may become visible in a short time and take the form of necrotic lesions (dead tissue) or it can develop slowly and become manifest as a yellowing or chlorosis of the leaf. There may be a reduction in growth of various portions of a plant or a loss in reproductive parts or in yield. Plants may be killed outright but they usually do not succumb until they have suffered injury perennially.

Injury may not be visible externally occurring subcellularly in cell membranes and chloroplasts (plant organelles where photosynthesis takes place). The plants may suffer physiologically due to an upset in the rate of photosynthesis, respiration or transpiration.

Sulphur Dioxide

There is reference to the deleterious effects of sulphur dioxide on vegetation dating back more than 100 years in Europe. In the United States the Experiment Station of the Agricultural College of Utah published a bulletin in 1903 describing the effects of smelter smoke on Utah agriculture. In the 1930's an international problem arose when smelter fumes emitted by the Consolidated Mining and Smelting Company at Trail, British Columbia travelled down the Columbia River Valley to damage forests in Stevens County in the State of Washington. Comprehensive investigations were carried out for about 10 years resulting in the publication of a book by the National Research Council of Canada in 1939. Investigations in the Sudbury district of Ontario started in the 1940's and are still continuing.

Major sources of sulphur dioxide are coal burning operations, especially those providing electric power and space heating. Large quantities of sulphur dioxide can also result from the burning and refining of petroleum fuels and the smelting of sulphur-containing ores.

Sulphur dioxide enters leaves mainly through the stomata (microscopic openings where normal gas exchanges of oxygen and carbon dioxide occur). The toxicity of sulphur dioxide to the mesophyll cells (inner chloroplast-containing cells) of leaves is primarily due to its reducing properties.

Leaf injury is classified as either acute or chronic. Acute injury is caused by absorption of high concentrations of sulphur dioxide in a relatively short time. This results in a rapid accumulation of sulphite which is toxic to the metabolic processes taking place in the mesophyll cells.

Chronic injury is caused by long-term absorption of sulphur dioxide at sub-lethal concentrations. The sulphite formed is oxidized to sulphate at about the same rate that the gas is absorbed. When sulphate accumulates beyond a threshold value that the plant cells can tolerate, chronic injury occurs. It is estimated that sulphate is about 30 times less toxic than sulphite.

Acute sulphur dioxide injury on broad leaves takes the form of bifacial lesions, which usually occur between veins, and is often more prominent towards the petiole (leaf-stalk). The injury is local. The metabolic processes are completely disrupted in the necrotic or dead areas, with the surrounding leaf tissue remaining green and functional. The green pigments are decomposed and the affected leaf area assumes a bleached, ivory, tan, orange-red, reddish-brown or brown appearance, depending upon the plant species, time of year and weather conditions. The tissue on either side of the veins is extremely resistant. In some cases, injury can occur on the margins of leaves.

Young leaves rarely display necrotic markings whereas newly expanded leaves are most sensitive to sulphur-dioxide injury. The oldest leaves are moderately sensitive. In monocotyledonous (blade-like) leaves the injury can occur at the tips and in lengthwise areas between the main veins. In conifers acute injury usually appears as a bright orange-red tip necrosis on current-year needles, often with a sharp line of demarcation between the injured tips and the normally green bases. Occasionally the injury may occur in bands in apical, medial or basal locations on the needles.

Chronic sulphur-dioxide injury becomes manifest as a yellowing or chlorosis of the leaf, sometimes from lower to upper surfaces on broad leaves. Occasionally only a bronzing or silvering will occur on the undersurface of the leaves. The rate of metabolism is reduced in leaves displaying chronic injury. In conifers chronic injury on older needles is first indicated by a yellowish-green colour that changes to reddish-brown starting at the tips and developing basipetally (toward the base).

Different plant species and varieties and even individuals of the same species may vary considerably in their sensitivity or tolerance to sulphur dioxide. Susceptibility lists have been made by several investigators but they can be only used as a guide. Variations can occur because of differences in geographical location, climate, and plant stage of growth and maturation.

In cities, trees found resistant to sulphur dioxide pollution in descending order were Ailanthus, gingko, Carolina poplar, pin oak, sycamore, Norway maple and little-leaf linden.

Environmental factors conducive to optimum plant growth usually abet sulphur-dioxide injury. They include sunlight, moderate temperature, high relative humidity, wind and adequate soil moisture.

Most investigators have shown a direct relationship between open stomata and the absorption of sulphur dioxide and subsequent leaf injury. When stomata are closed, either at night because of darkness or during the day because of other factors, plants are more resistant to sulphur dioxide.

Vegetation is most susceptible to sulphur dioxide during the active growth months of June, July and August. If the environmental factors and growth stages of the plants are not conducive to injury, the plants will escape injury even in the presence of potentially damaging concentrations of sulphur dioxide. For foliar injury to occur, 0.25 parts per million (ppm) of sulphur dioxide for eight hours or 1.0 ppm for one hour must be present.

Fluorides

Fluoride injury to vegetation was recognized in Germany over 60 years ago. In addition to vegetation damage, livestock was affected in the vicinity of certain industries.

Fluorides may be discharged into the atmosphere from the combustion of coal; the production of brick, tile, enamel frit, ceramics, and glass; the manufacture of aluminum and steel; the production of hydrofluoric acid, phosphate chemicals and fertilizers.

Plants may be injured when exposed for long periods to atmospheric concentrations of fluoride of less than 1 part per billion (ppb). Similar injury symptoms may be produced by higher concentrations for shorter periods of time. The amount of fluoride accumulated in plant tissues depends on the absorption capacity of the plant, its sensitivity to fluorine and ambient air concentrations. High concentrations of fluoride may accumulate in leaves during the growing season while subjected to extremely low concentrations in the air. The cotton plant can concentrate more than 5000 ppm fluoride without showing any visible injury, whereas the sensitive gladiolus exhibits leaf injury with less than 35 ppm fluoride.

Fluorides absorbed by leaves are translocated towards the margins of broad leaves and to the tips of monocotyledonous leaves and coniferous needles. Little injury takes place at the sites of absorption, whereas the margins or tips of the leaves build up lethal concentrations, resulting in necrosis. The rates of translocation and concentration of fluoride are of primary importance with regard to explaining injury to sensitive plants.

Fluoride injury starts as a gray or light-green water-soaked lesion which turns tan to reddish-brown. It can appear within a few hours or a week after exposure depending on plant species and variety, the concentration of atmospheric fluorides, the duration of exposure and various environmental conditions. With continued exposure, the necrotic areas increase in size spreading inward to the mid-rib on broad leaves and downward on coniferous needles.

Chemical analysis of injured foliage may show abnormally high values of fluoride. On the same pine tree, analyses showed 129 ppm in current-year needles and 462 ppm in three-year-old needles that had been subjected to atmospheric fluoride for a longer period of time. Fluoride content of foliage will also be higher nearer the source of aerial contamination.

Fluorides inhibit photosynthesis, the impairment being measurable even before visible leaf injury occurs. With continued fumigation, the decrease in photosynthesis rate parallels the increase in leaf tissue necrosis. Fluorides inhibit enzymes in vitro. A well-known example is enolase, an enzyme required in the glycolytic pathway of plant respiration.

A study of tree susceptibility to fluorides showed young pine needles to be most vulnerable followed by apricot, prune, peach, apple and oak. Old pine needles were the least susceptible.

Atmospheric fluorides, by concentrating in foliage and directly injuring plants, pose a threat to the health of livestock. Forage crops may appear normal while actually containing high concentrations of fluoride. Alfalfa, for example, can tolerate several hundred ppm fluoride without showing visible injury. Cattle, feeding on this plant over an extended period of time, may develop the disease fluorosis if the fluoride content is in excess of 40 ppm. The symptoms of chronic fluorine toxicosis are mottled and abraded teeth, swollen periosteal (bone surface) tissue, lameness and, in severe cases, decreased appetite and milk production.

Ozone and PAN

Ozone and PAN (peroxyacetyl nitrate) are the main phytotoxicants in the Los Angeles type of oxidant smog now plaguing many urban areas. Automobile exhaust is the major contributor of the reacting substances to the atmosphere.

Oxidant damage to plants was first observed in the Los Angeles area in 1944. A wide variety of plants are susceptible to oxidant damage. Ozone causes a spotting, bleaching or chlorosis of upper leaf surfaces. PAN causes bronzing, silvering, or glazing of lower leaf surfaces. Typical lesions are produced by concentrations of ozone as low as 0.05 ppm for four hours. About 14 ppb of PAN in ambient air have injured plants in California. Light is necessary before, during and after a fumigation by PAN to cause visible injury.

In addition to visible injury, growth suppression may result from the effects of oxidants decreasing photosynthesis and changing cell membrane permeability.

Herbaceous plants (tobacco, bean, beets, celery) and the so-called "salad crops" (spinach, lettuce and endive) are very susceptible to smog injury.

Susceptibility to ozone injury is influenced by environmental and plant factors. It is increased by high relative humidity and low carbohydrate content. Ozone injury to broad leaves displays a definite pattern related to the development of functional stomata. The youngest leaves are resistant and with expansion become susceptible at their tips. With increasing maturity the leaves become successively susceptible at middle and basal portions. The leaves become resistant again at complete maturation. Peculiarly, ozone usually enters through the stomata on lower leaf surfaces but injures palisade mesophyll cells in the upper layers of the leaf. In these cells the chloroplasts disintegrate followed by plasmolysis (contraction) and desiccation (drying up) of the cellular contents.

Recent work has shown that sulphur dioxide and ozone may act synergistically in an air pollution mass to reduce the required concentrations of either gas to produce leaf injury. Ozone as low as .027 ppm when combined with 0.24 ppm sulphur dioxide injured Bel W3 tobacco plants in two hours.

Nitrogen Dioxide

Nitrogen dioxide in high concentrations (over 3 ppm for about two hours) can cause plant injury symptoms similar to those caused by sulphur dioxide. Low light intensity increases sensitivity of plants. Nitrogen dioxide can injure the same plants as ozone and in the same physiological tissue. Injury symptoms are different, however, and approximately ten times as much nitrogen dioxide is required. Long-term exposures of plants to low concentrations of nitrogen dioxide (0.5 ppm) may suppress plant growth, distort the leaves and increase the green color (chlorophyll content) of the leaves.

Chlorine

Chlorine is not widespread in the atmosphere. It is usually confined to the immediate area surrounding its source. High concentrations of chlorine released in tank car accidents can cause severe defoliation and leaf injury to contiguous vegetation. Chlorine is less toxic to plants then fluoride, requiring about 0.1 ppm for two hours to injure sensitive herbaceous species. It is a little more phytotoxic than sulphur dioxide requiring about one-half the concentration to produce similar symptoms of injury.

Particulate Matter

Particulate matter such as cement dust, magnesium-lime dust and carbon deposited on vegetation inhibit photosynthesis. Sulphuric acid aerosols produce punctate spots on the upper surfaces of wet leaves. Cement dust may cause chlorosis and death of leaf tissue by the combination of a thick crust and alkaline toxicity produced in wet weather. Deciduous and coniferous trees are injured, the latter occasionally killed. Accumulation of alkaline dusts in soil can increase soil pH to levels adverse to crop growth.

Investigating Air Pollution Injury to Vegetation

Any resident of Ontario who suspects that his plant life (ornamentals, crops, orchards or woodlands) is being affected by air pollution can make a complaint to the Phytotoxicology Section. An investigation will be carried out to determine the cause of injury. If diagnosed as air pollution injury and the source is detected, a report of the investigation is sent to both the complainant and the offending source. Abatement engineers are notified to inspect the offending source to prevent further phytotoxic emissions.

The Air Management Branch encourages private settlement of damages. If this is not feasible, the claimant can request mediation by a three-man Board of negotiation established in 1968 under the Air Pollution Control Act, 1967.

The investigation of an air pollution vegetation complaint at times may be compared to a "Whodunit". Research experience and the application of detective work to plant pathology techniques are essential. Some complaints are solved readily; others require lengthy investigations.

One complainant property was surrounded by seven industries. The local Air Management engineer wanted to know what pollutant caused the vegetation injury and which industry was responsible. Through careful investigation of the pattern of injury on both complainant and neighbouring properties, through the knowledge of air pollution injury symptoms and the susceptibility and resistance of various plant species, by examining wind records and by chemically analyzing collected vegetation, it was found that the injury was caused by an acute fumigation of sulphur dioxide and that the source was a sulphite pulp and paper mill.

Not only were the complainant and the offending source brought together for settlement of damages, but the industry also purchased new control devices to prevent any further accidental release of high concentrations of sulphur dioxide.

In another investigation of an acute episode, the vegetation injury area was situated between two industries -- an aluminum chloride manufacturer about one mile west and a nickel refinery about one mile southwest.

Phytotoxicology personnel made a detailed vegetation survey in the area. No pollution injury was observed near the industry to the west or at locations midway between the injury area and this industry. In the injury area, it was found that trees, shrubs and hedges displayed severe foliar injuries only on their southwest sides.

Samples of collected foliage and soil were analysed for several pollutants that the two industries could emit, such as sulphur, fluoride, chloride, aluminum, copper and nickel. The results showed that sulphur and fluoride contents were normal when compared to control collection analyses, that chloride, aluminum, and copper levels were slightly elevated, whereas nickel contents were present in excessive and toxic quantities. Since nickel was one of the pollutants emitted from the industry to the southwest, this industry was implicated as the offending source.

Some injuries investigated are due to other causal agents. During the summer of 1970, several complaints were received concerning injury to European mountain ash trees in Cornwall. Upon investigation, it was found that some of the injuries had indeed been due to air pollutants from local sources, but that for the most part the injuries were caused by the disease Cytospora canker which was rampant in the area at the time.

In Scarborough, an investigation into the death of Lombardy poplar trees next to a manufacturer of liquefied gases showed that the trees were being killed by the disease Dothichiza canker. Injury to Chinese Elm trees in Windsor was found attributable to the seepage of toxic chemicals from a neighbouring waste pond.

In a new subdivision of St. Catharines, the decline and death of certain trees was due to careless workmanship on the part of building contractors. Trees left standing for landscaping purposes had been severely bruised by trucks and bulldozers and the grade had been altered to the extent that five feet of excavated subsoil covered the original bases of some of the trees. The added soil interfered with the availability of air, water and nutrients for the tree roots, causing root death and above-ground tree decline.

These cases illustrate how other causal agents can injure vegetation creating symptoms that mimic those brought on by air pollution. When it is determined that injury is being caused by a biological agent or by poor management, the grower is advised to seek combative measures or management advice from the agency authorized to handle such matters.

Prevention of Phytotoxic Effects

The protection of plants from the adverse effects of aerial phytotoxicants cannot be carried out in exactly the same manner as is possible with disease-causing, organic reproductive bodies. A pollution-diseased plant cannot infect another plant; thus there is no need for a quarantine or for eradication of the affected plants. In certain instances, sprays and dusts have protected plants from air pollution injury. The development of resistant varieties holds some promise. The best control method, however, is to reduce the concentrations of noxious pollutants at their sources so as not to exceed the established air quality criteria for agriculture and forestry.

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An Introduction to Air Pollution
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Environment Conservation in Ontario

Department of Energy and Resources Management

Hon. George A. Kerr, Q.C., Minister J.C. Thatcher, Deputy Minister

AN INTRODUCTION TO AIR POLLUTION AND ITS CONTROL IN ONTARIO

Air pollution control is a matter of vital concern to us all. Each of us, on average, breathes 22,000 times a day, taking in about 35 pounds of air in the process. It is our main link with life, far exceeding our dependence on food and water. An adult might live six weeks without food, three days without water, but only minutes without air. Its quality must be protected.

What Is Air Pollution?

In simple terms, air pollution exists when certain substances are present in the atmosphere in sufficient concentrations that they adversely affect the environment.

As defined in Ontario's Air Pollution Control Act, 1967, air pollution is "... the presence in the outdoor atmosphere of any air contaminant or contaminants in quantities that may cause discomfort to or endanger the health or safety of persons, or that may cause injury or damage to property or to plant or animal life or that may interfere with visibility or the normal conduct of transport or business.

Historical Background and First Attempts at Control

Air pollution is not a new problem. It is caused by a variety of natural phenomena as well as by human activities and has been present since the earth began.

Natural air pollution results from volcanic eruptions, earthquakes, forest fires and even simple wind action. Bacteria, pollen and salt crystals (the last from the surfaces of large bodies of salt water) can be carried by wind, for example, for great distances before being deposited. Sea-water salt in fact has been found in the prairie provinces.

Man began contributing to air pollution with his first fire and he steadily continued to do so during his development through the ages of fire, copper, bronze, iron and steel down to the present age of atomic power and space travel. Even so, all but two air pollutants are still produced in far greater tonnages by natural processes than by modern

industry. Man outdoes nature only in the production of sulphur dioxide and carbon monoxide.

British recorded history shows how long air pollution has been a problem in that country.

In 1257, the smoke of Nottingham was so bad that Queen Eleanor, who was staying there while Henry III led an expedition into Wales, was compelled to move to Tutbury.

In 1306, Edward I issued a royal proclamation prohibiting the use of coal in certain furnaces. Punishment for the first offence was a fine; for the second, demolition of the furnace; for the third, execution. One such execution actually took place.

In 1661, coal smoke was so bad in London that the diarist John Evelyn, in writing about it stated, "... the weary Traveller, at many miles distance, sooner smells, than sees the City."

Initially, air polluting activities were limited to small settlements and towns and they were treated as individual smoke and odor problems because only those people living close to actual sources were affected. With the coming of the Industrial Revolution, however, the situation rapidly changed. Cities grew and air pollution incidents increased in both frequency and complexity resulting in total pollution of entire metropolitan air spaces.

In England, the smoke problem began to be attacked on a community basis in the 19th century. The first anti-smoke ordinance was adopted in 1857. In the United States, the first such law was put into force in Chicago in 1881. In Canada, a Toronto by-law was passed in 1907.

In the 20th century, the resources of science and technology began to be applied more fully to the control of municipal air pollution as greater knowledge of the nature and control of air pollution started to emerge.

In the early part of the century, control programs were designed to control visible emissions, primarily smoke. It is only in the last 20 years that legislation has been passed concerning invisible air pollution. (1) During this period, the problem has commanded the attention of professionals from many specialized disciplines -- engineering, law, public administration, economics, medicine and numerous areas of pure science.

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(1) When the term "air pollution" is used, it is usually done so with regard to smoke pouring out of a chimney. Actually, the smoking chimney is only one source of air pollution. There are many others producing both visible and invisible contaminants. Carbon monoxide is an obvious example of invisible pollution. Another is cigarette smoke. Its gases and particles remain in the air long after disappearing from actual view.

Sources of Air Pollution

Air pollution is a major by-product of a civilization that has become dependent upon industrial technology for survival. Our age is one of complex production techniques, sophisticated forms of transportation, mass communication, rapid distribution systems for the delivery of raw materials and manufactured products, centralized energy and heat sources, intricate urban structures. All aspects are involved in the production of air pollution which results from three basic processes:

1. Combustion

2. Vaporization

3. Mechanical attrition

Combustion

The combustion of fossil fuels and waste materials for heat, steam and electrical energy is required for warmth, metal melting, motive power, food processing, incineration of waste materials, baking, tempering, curing and many other operations. The products of combustion -- smoke and gases -- comprise what are known as "contaminant plumes," the familiar trademarks of all industrial areas.

Vaporization

Vaporization, or volatilization, is a by-product of many chemical and manufacturing operations which induce physical changes in substances through the application of heat and pressure, thereby causing some component materials to vaporize into the atmosphere.

Vaporization includes the evaporation of volatile materials at normal atmospheric temperatures and pressures; fuming, as a result of induced temperatures; and decomposition of organic materials due to natural processes. Materials that evaporate at normal atmospheric temperatures and pressures include petroleum derivatives such as gasoline, fuel oil, paint and cleaning solvents.

Fuming includes both volatilization and condensation. It takes place in acid manufacturing and handling, and in metal melting operations where molten metal liquids are first volatilized to the gas state and then condensed to dusts by rapid cooling. Decomposition is associated with the handling of highly organic compounds or animal tissue with nitrogenous or sulphurous contents.

Mechanical Attrition

Mechanical attrition includes crushing, grinding, drilling, demolishing, mixing, batching, blending, sweeping, sanding, cutting, pulverizing, spraying, atomizing, etc., all of which either directly or indirectly disperse particulates in the form of dusts or mists into the atmosphere. These activities are everyday aspects of modern life and industry.

Types of Air Pollution

Air pollution consists of either one or a combination of the following physical states:

1. Aerosols and particulates (mists and dusts)

2. Organic gases

3. Inorganic gases

1. Aerosols and Particulates

The diameters of contaminant particles emitted from man-made sources vary greatly in size from 1,000 microns (the size of raindrops) to substantially less than one micron. (The micron is a microscopic unit measure equivalent to 1/1,000 of a millimetre, or 1/25,000 of an inch.) Cigarette smoke particles range in size from 0.01 to 0.5 micron. Particles smaller than 10 microns tend to remain suspended in air. Larger particles tend to settle upon available surfaces.

Aerosols are usually taken to mean particles which range in size from 10 microns to something less than 0.01 micron. Most aerosols are considered to be less than 1 micron in diameter.

Particulate matter is responsible for two basic air pollution effects:

1. Soiling, corrosion, injury to clothing, property and crops as a result of deposition.

2. Adhesion of particulate matter to respiratory tissues with possible physiological impairment or damage. Particulate matter may include toxic substances, possibly carcinogens and radioactive materials.

Aerosols tend to remain suspended permanently in the air. They are usually emitted either in aerosol form or evolve from the fracturing or decomposition of large particulates. They also form in the air from the condensation and nucleation of gaseous contaminants. They may be organic or inorganic in composition, and either liquid or solid.

The smaller the aerosols, the more they behave like a gas. Aerosols, therefore, are not as readily deposited as the particulates and may be inhaled and exhaled with air. Aerosols are also important because of their ability to reduce visibility through the process of light scattering.

2. Organic Gases

Organic gases are hydrogen-carbon compounds and their derivatives. They include all classes of hydrocarbons (olefins, paraffins and

aromatics) and the derivatives formed when hydrogen is replaced by oxygen, halogens, nitro or other substituent groups.

The principal origin of hydrocarbons is petroleum. Hydrocarbons and their derivatives are released to the atmosphere during the refining of petroleum and the transfer, storage and use of petroleum products (fuels, lubricants and solvents). They are also formed in the atmosphere due to certain photochemical reactions.

The most important source of hydrocarbon emission is the gasoline-fuelled motor vehicle, especially in heavily populated areas. The other major class of hydrocarbon contributor consists of industrial and commercial users of organic solvents. They and their counterparts in the petroleum industry account for 98% of all hydrocarbon emissions.

Hydrocarbons and their derivatives are important because of their role in the production of photochemical smog. Most reactive are the olefins (unsaturated hydrocarbons). They can react with nitrogen dioxide to produce visibility-reducing aerosols and oxidants (primarily ozone) causing plant damage and eye irritation.

Paraffins (saturated hydrocarbons) and aromatic hydrocarbons can also react with nitrogen dioxide to produce a similar variety of irritating effects. Hydrocarbon derivatives produced by photochemical reactions include aldehydes, ketones, and nitro-substituted organics that in turn react to worsen smog effects.

3. Inorganic Gases

Major inorganic gases are oxides of nitrogen, oxides of sulphur and carbon monoxide. Of less importance with regard to air pollution are ammonia, hydrogen sulphide and chlorine. Principal source of the oxides is fuel combustion --industrial, commercial and domestic for purposes of transportation, space heating and power generation.

Oxides of nitrogen: There are many oxides of nitrogen but only nitric oxide (NO) and nitrogen dioxide (NO_2) are important as air contaminants. Nitric oxide is formed when atmospheric nitrogen is oxidized during fuel combustion in automobiles, incinerators and industrial furnaces. The amounts produced are in direct proportion to fuel consumption, increasing tremendously at high temperatures.

Once in the atmosphere, nitric oxide is then able in the presence of sunlight to combine with available atmospheric oxygen to form nitrogen dioxide, one of the major ingredients, as mentioned above of photochemical smog. Oxides of nitrogen have increased in quantity lately, largely due to the greater compression ratios and engine temperatures of late model motor vehicles.

Oxides of sulphur: Only two oxides of sulphur -- sulphur dioxide (SO_2) and sulphur trioxide (SO_3) -- are classified as air contaminants. They are formed primarily during the combustion of fuels that contain sulphur (e.g., coal and oil). The amounts produced, therefore, are

direct functions of fuel sulphur content and total fuel consumption. Normally, sulphur dioxide is produced in far greater quantities than sulphur trioxide. The latter is formed only under rather unusual conditions.

Gaseous oxides of sulphur are significant because of their toxicity. They have been associated with illness arising from many severe air pollution episodes although the exact relationship, even at concentrations found in the most heavily industrialized community, is still ill-defined.

Each oxide can combine with water in the air to form toxic acid aerosols that corrode metal surfaces, fabrics and plant leaves. Sulphur dioxide, in particular, causes a characteristic type of vegetation damage whereby portions of leaves are bleached in a specific pattern. In concentrations as small as 5ppm., sulphur dioxide is irritating to the eyes and respiratory system. It is colorless with a characteristically pungent suffocating odor.

Carbon monoxide: Carbon monoxide (CO) results from the incomplete combustion of carbonaceous fuel. Automobiles are the principal source, contributing as much as 97% of the total amount in a large metropolitan area. The exhaust from an individual car is one to five per cent carbon monoxide depending upon carburetor adjustment. Although produced in enormous quantities throughout the world, carbon monoxide forms only .00001 per cent of the atmosphere. It is presumed that most of it is oxidized to carbon dioxide (CO_2).

Carbon monoxide is poisonous to man and animals. In suitable concentrations, it acts as an asphyxiant interfering with the blood's ability to carry and release oxygen. Initial symptoms are slight headache and shortness of breath. In sufficient concentrations, it is, of course, fatal.

In general, toxicologists hold that concentrations of carbon monoxide would have to exceed 500 ppm for at least one hour before a detectable effect upon human health is produced. Carbon monoxide has been detected in urban atmospheres at concentrations ranging from substantially 0 to 150 ppm. Greater concentrations have occasionally been measured in confined spaces such as tunnels and large, poorly ventilated garages. As yet, atmospheric concentrations have not been linked to fatalities.

Miscellaneous Inorganic Gases: Ammonia, hydrogen sulphide, chlorine, fluorine and fluorides are normally detectable in only trace quantities in the atmosphere but all are toxice in small to moderate concentrations. The first three have unpleasant odors.

Hydrogen sulphide can cause discoloration of certain kinds of paint. Ammonia can discolor certain fabric dyes and is corrosive to copper, brass, aluminum and zinc. Chlorine can discolor certain fabric dyes. Fluorine and fluorides, especially hydrogen fluoride, are highly toxic and corrosive. They can cause damage to vegetation, and illness and injury to humans and animals.

Effects of Air Pollution

As air pollution increases, certain effects become apparent. Visibility is reduced, vegetation is injured, property and clothing are soiled and, most vital of all, human health is affected.

Visibility Reduction

Reduction in visibility is due to the concentration of aerosols in the atmosphere. There are two basic effects:

1. Sky darkening

2. Haziness (light scattering)

Sky darkening is the physical obstruction of sky illumination due to clouds of contaminants or plumes of smoke and fumes.

Haziness is the alteration of sky illumination due to light scattering. The blue color of the sky is the result of sunlight being scattered by molecules of atmospheric gases. Similarly, the color of the sky can be altered by pollution hazes. Type and degree of alteration depends upon the size of aerosols present relative to light wave length. Aerosols 0.4 to 0.9 microns in diameter are most effective in light scattering.

Visibility reduction is an indication of pollution accumulation and its measurement is one way in which pollution intensity can be determined. Visibility records can be used to show daily, weekly, monthly and yearly variations. They reflect not only weather variations but also changes in industrial practices and the effects of pollution control procedures.

As the sky is darkened, either by normal cloud or pollution effects, the amount of available sunlight reaching the ground is reduced. As sunlight is essential to human and plant life, its obstruction due to any cause can be a serious matter if it occurs often or for prolonged periods.

Vegetation Injury

Injury to crops and trees resulting from air pollution has been clearly established. It can range from visible markings on foliage to reduced growth and yield to premature death of plant life. The ensuing visual and economic consequences can at times be disastrous. Injury to crops possessing marketable foliage such as lettuce or tobacco can result in especially high losses.

Vegetation injury often serves as a warning to man of the presence of toxicants that may also affect human health and poison foraging cattle. In addition, it can sometimes be used as an indicator of the chemical reactivity of the air.

Vegetation in Ontario suspected or known to have been injured by air pollutants include ornamental flowers, garden fruits and vegetables, stored vegetables, greenhouse chrysanthemums and roses, farm crops (white beans, tomatoes, green onions, winter wheat, oats, and corn), animal pastures and cured hay, and fruit and forest trees.

Suspected air pollutants and those ascertained as having caused vegetation injury include fluorides, sulphur dioxide, oxidants, boron, lead chlorine, hydrogen chloride, liquefied gases, chromium, nickel, salt spray, urea, nitrogen dioxide, ammonia, cement dust, magnesium-lime dust, flyash and detergents. Any pollutant that injures vegetation is known as a phytotoxicant.

Injury to foliage may become visible in a short time and take the form of necrotic lesions (dead tissue) or it can develop slowly and become manifest as a yellowing or chlorosis of the leaf. There may be a reduction in growth of various portions of a plant or a loss in reproductive parts or in yield. Plants may be killed outright but they usually do not succumb until they have suffered injury perennially.

Injury may not be visible externally occurring subcellularly in cell membranes and chloroplasts (plant organelles where photosynthesis takes place). The plants may suffer physiologically due to an upset in the rate of photosynthesis, respiration or transpiration.

The symptoms of injury caused by phytotoxicants can be very similar to those of injuries caused by disease, insects, adverse weather, poor nutrition or mismanagement. All suspected cases require careful diagnosis by specialists.

The protection of plants from the adverse effects of aerial phytotoxicants cannot be carried out in exactly the same manner as is possible with disease-causing, organic reproductive bodies. A pollution-diseased plant cannot infect another plant; thus there is no need for a quarantine or for eradication of the affected plants. In certain instances, sprays and dusts have protected plants from air pollution injury. The development of resistant varieties holds some promise. The best control method, however, is to reduce the concentrations of noxious pollutants at their sources.

Soiling and Property Damage

One of the first material effects of air pollution is the soiling of clothing, buildings and properties. Air pollution has a direct influence on the cost of cleaning and laundering, the marketability of merchandise and the cleaning of buildings. It is responsible for considerable economic loss.

Property damage is usually of a cumulative nature. It tends to shorten the durability of materials exposed to the atmosphere. It is generally caused by the interaction of contaminants with the surface or protective coatings of materials.

Typical effects are metal corrosion, stone and masonry deterioration excessive cracking of rubber tires and damaged automobile paintwork.

Health Effects

Effects on human health have been most dramatic during so-called air pollution "episodes." These are fortunately rare. They occur when stagnant weather conditions allow a concentration of air pollutants to build up over a period of several days. At such times, people with severe chronic respiratory disease are greatly affected and many excess deaths can occur.

Serious pollution episodes have occurred in various parts of the world including the Meuse Valley of Belgium; Donora, Pennsylvania; New York City; London, England. Of these, the Donora and London episodes provide particularly dramatic evidence of the effects of air pollution.

In Donora, an industrial community located in a deep valley 30 miles south of Pittsburgh, thousands of people became ill, several hundred were hospitalized and 20 died when air pollutants from mills, smelters and acid plants accumulated during a calm period of weather in October, 1948 and did not disperse for four days.

In London, a much more serious episode, perhaps the worst in history, occurred in December, 1952. Again, during calm weather, air pollution became so concentrated that 4,000 deaths resulted from various respiratory diseases both during and after the episode.

The effect of day-to-day exposure to lower concentrations of air pollution is very difficult to assess. Some individuals are relatively susceptible, others less so. On the whole, people who live in industrial centres have an increased chance of getting certain diseases of the respiratory system.

Some forms of air pollution are more annoying than harmful. This is true of many unpleasant odors. Where the main source of pollution is the automobile, the air may cause the eyes to tear and the throat to be irritated without having any apparent lasting effect. Much research is still required to determine the real long term effects of exposure to polluted air.

Meteorology and Air Pollution

Meteorological factors greatly effect the amount of pollution present in the atmosphere. Temperature and solar radiation, by their influence on the amount of space heating required, affect the quantities of pollutant emitted. Sunshine is required for the photochemical production of oxidants that form smog.

Wind velocity, turbulence and stability affect the transport, dilution and dispersion of pollutants. Rainfall has a scavenging effect by washing out particles in the atmosphere. Finally, humidity is a frequent and important factor in determining the effect of pollutant concentrations on property, vegetation and health.

Meteorological parameters having the most important influence on the diffusion of pollutants in the atmosphere are wind direction and speed, turbulence, temperature and stability.

Wind

Wind is air in motion in three dimensions. Only the horizontal component, however, is usually considered in terms of direction and speed.

Wind direction indicates direction of travel of pollutants. It is a very important factor in predicting the air pollution potential of an area in which the principal pollutant sources are high stack emitters located close together. Wind direction is less important where low level emitters (low smoke stacks, automobiles etc.) cause most of the pollution.

Expected persistence of wind direction, related to topographic features and location of receptors, must also be considered both when forecasting air pollution potential and selecting sites for plants. Topographical features such as valleys cause winds to persist in certain directions at much greater frequencies than others. Obviously, large industries should not be located in such areas.

Wind speed determines the travel time of pollutants from a source to a receptor. Wind speed also has a dilution effect. Pollutant concentrations downwind from ground level sources are inversely proportional to wind speed.

This dilution effect is not true for hot emissions from high stack sources. In these instances, an increase in wind speed lowers the plume rise, thus tending (up to a point) to increase ground level concentrations. There is a "critical wind speed" for each stack design at which concentrations downstream reach a maximum.

Turbulence

High frequency fluctuations in the wind are known as turbulence and they occur both vertically and horizontally. These random motions

are responsible for the movement and diffusion of pollutants about the mean wind path.

Mechanical turbulence is caused by roughness of terrain -- trees, shrubs, buildings, etc. Thermal turbulence is due to the earth's surface being heated by the sun. Thermal eddies develop as the air, heating up at lower levels first, becomes less dense and rises.

Temperature

The temperature of the lower region of the atmosphere (surface to 2 km.) can either decrease or increase with height depending on the character of the underlying surface and the radiation at the surface. During the day, temperature usually decreases with height. As a result, the warmer air near to the ground and the pollutants emitted into it rise and disperse high into the atmosphere. Concentrations of pollutants in the lower layers of the atmosphere are relatively low.

When the reverse occurs and temperature increases with height, a temperature inversion is said to exist. An inversion inhibits the rise and dispersion of pollutants emitted in the atmosphere. Thus, when pollutants are emitted near the ground during an inversion, they remain and cause high concentrations to develop.

The Automobile and Air Pollution

The automobile is a major source of air pollution. In addition to carbon dioxide and water vapour, its exhaust emissions contain carbon monoxide, oxides of nitrogen, unburned hydrocarbons and lead.

Automotive pollutants result from the incomplete burning of fuel. When there is sufficient oxygen, hydrocarbon fuel is completely converted into carbon dioxide and water vapor. Incomplete combustion also produces carbon monoxide, hydrocarbons and oxides of nitrogen.

Incomplete combustion can occur for various reasons -- poor mixing of air and fuel, short combustion time, quenching of the combustion process near a cool chamber wall, dead space where the combustion flame can not penetrate.

Some of these problems can be reduced or eliminated by fine tuning of the carburetor and timing mechanism, by heating the air or fuel prior to mixing, or replacing the standard carburetor with a fuel injection system.

Crankcase emissions are eliminated by using a PCV (positive crankcase ventilation) valve that feeds crankcase vapors back to the air intake system to be burned in the combustion chamber. Gasoline evaporating through either the fuel tank breather tube or carburetor can be greatly reduced by terminating such tubes and other outlets with an activated charcoal filter that absorbs escaping vapors.

A catalytic muffler containing certain types of catalysts can be used to oxidize toxic gases in the exhaust. Due to the poisoning effect that lead has on the catalyst, however, the system can only be used with gaseous fuels, diesel fuel or unleaded gasoline.

Possible alternatives to the internal combustion engine are an electric power source, a modified steam engine and the gas turbine. Of special interest at present is the gasoline-electric hybrid that can be run on either gasoline or electric power.

Air Pollution Control In Ontario

Action against air pollution in Ontario began, as in most other jurisdictions, at the municipal level with the passing of local by-laws restricting smoke emissions.

In 1955, the Ontario government appointed a select committee to study the problem of air pollution and its control. As a result of the committee's report, the province passed its first Air Pollution Control Act in 1958. It delegated the control of air pollution to municipalities but widened the scope considerably to provide for the control of all sources of air pollution.

Actual provincial involvement under the 1958 legislation was purely advisory. In 1963, however, the Act was amended to give the province a more direct role. It undertook the approval of new sources of industrial air pollution, instituted a training program for municipal inspectors and established a program of financial assistance.

Attempts to stimulate air pollution control activity at the municipal level proved largely unsuccessful. Only four municipalities employed full-time staff. During the middle 1960's, it became readily apparent that serious headway could only be made by a centralized authority.

The province assumed full responsibility for the control of air pollution with the passing of the Air Pollution Control Act, 1967. The Act became effective January 2, 1968, and the Air Pollution Control Service of the Department of Health was named enforcement agency. In 1969, the Service was transferred to the Department of Energy and Resources Management Branch and renamed the Air Management Branch.

Scope of Air Pollution Control Act, 1967

Under the Act, the Ontario Government, through the Minister of Energy and Resources Management and the Air Management Branch, possesses broad powers allowing it to:

1. conduct air quality and meteorological studies and monitoring programs.
2. establish acceptable air quality levels.
3. inspect and regulate all sources of air pollution.
4. order, after investigation, the discontinuance of the discharge of any air contaminant. This action is reserved for unusual cases where such a discharge creates an immediate and serious danger to public health, and where a delay in following the usual procedures under the Act would prejudicially affect the public.

5. initiate legal action for violation of either a regulation made under the Act, or of a Minister's Order issued to correct a pollution condition. Maximum fine for an individual is \$2,000; for a corporation, \$5,000 on first conviction and \$10,000 on second conviction. Each day that a violation occurs constitutes a separate offence.

Numerous regulations have been made under the Act. Of special importance are those regulations that established an air pollution index, standards for emitted contaminants, criteria for desirable ambient air quality, standards governing the sulphur content of fuels sold in Metropolitan Toronto and air pollution emission standards for motor vehicles, ferrous foundries and asphalt paving plants.

Non-legislated guidelines include criteria for the design and operation of incinerators and conical wood waste burners and a suggested code of practice covering the establishment of livestock buildings and the disposal of animal wastes.

Controlling Stationary Sources of Air Pollution

Prior to the 1967 Act, new industrial sources of air pollution, as already mentioned, had been subject to pre-construction government approval since 1963. In January, 1968, all new stationary sources of air pollution became subject to such approval.

At the same time, surveys were undertaken across the province to locate and assess existing sources of air pollution for which abatement programs began to be developed. As of April, 1971, most large and many smaller stationary sources of air pollution in Ontario have had or are about to have abatement programs established by which their polluting emissions are being either eliminated or reduced to acceptable levels.

Controlling Mobile Sources of Air Pollution

Mobile sources present a different control problem. Motor vehicles (automobiles, trucks, buses) come under provincial jurisdiction; ships, trains and aircraft do not.

Controls for certain classes of motor vehicles were brought into force at the beginning of the 1969 model year. Based upon regulations adopted first in California and later for all of the United States, they have been broadened in scope and made more stringent each successive year.

All aspects of ship, train and aircraft operation come under federal jurisdiction. The Air Management Branch can and does, however, enforce existing federal provisions concerning air pollution from these sources.

Smoke emissions from ships in Canadian waters are regulated under the Canada Shipping Act. Smoke emissions from locomotives and other railway property are regulated by Canada General Order O-26 issued by

the Board of Transport Commissioners for Canada. No regulations have been developed to control aircraft exhausts.

Limiting Air Contaminant Emissions: Design Standards

When the emission of an air contaminant cannot be entirely prevented from a new stationary source of air pollution or eliminated from an existing one, its amount can still be limited to a level that will not be harmful to either humans, animals, vegetation or property.

This is done by applying what are known as design standards to a source. It involves (1) calculating what the subsequent concentration of an emitted contaminant will be at point of contact with an object that could be adversely affected by it, and (2) comparing that concentration with the standard or maximum concentration allowed for the contaminant. If the calculated concentration is too high, modifications become necessary to reduce the amount of contaminant that is being or will be emitted at the source.

In certain instances, when there is no practical method of sufficiently reducing the contaminant at source, a tall stack will be permitted to disperse it over a wider area, thereby reducing ground level concentrations. Dispersion, however, is considered an interim measure only. The goal is elimination of pollutants at their source.

The point of contact mentioned above is referred to as the "point of impingement". It can occur at ground level itself or above ground (e.g., the side of a building). Concentration figures at point of impingement are averages calculated for periods of 30 minutes. The maximum concentration allowed for a given contaminant is well below that at which adverse effects would actually occur.

Maximum allowable concentrations at point of impingement have been established for 20 different contaminants: ammonia, beryllium, bromine, cadmium oxide, carbon bisulphide, carbon monoxide, chlorine, dustfall, fluorides, hydrogen chloride, hydrogen cyanide, hydrogen sulphide, iron, lead, lime, nitric acid, nitrogen oxides, silver, sulphur dioxide, suspended particulate matter. Tentative standards are set when necessary for other contaminants. They are incorporated into regulations when their validity has been fully established.

The maximum allowable concentration of sulphur dioxide at point of impingement is 0.3 parts per one million parts of air by volume averaged over a period of 30 minutes. The maximum allowable concentration of suspended particulate matter at point of impingement is 100 micrograms per cubic metre of air averaged over a period of 30 minutes.

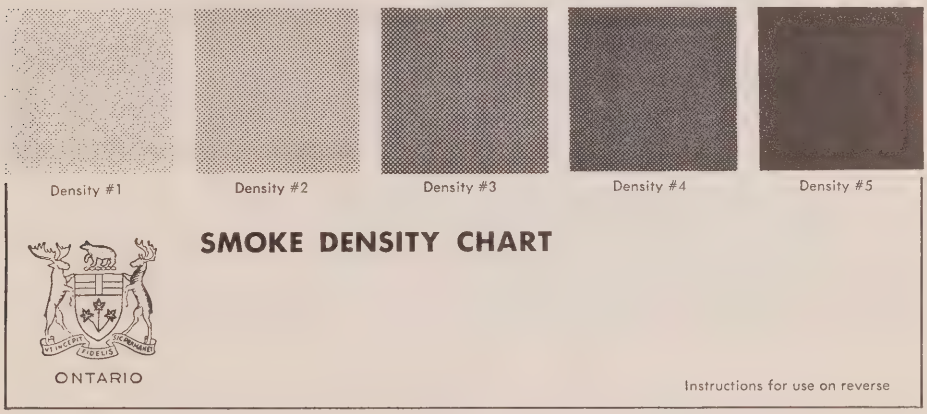
The calculation of a contaminant's concentration at a given point away from its source is a complex procedure beginning with a full evaluation of the equipment and processes involved to determine the contaminant's emission rate to the atmosphere (usually through a stack). When the emission rate is known, the concentration at point of impingement can be calculated. The physical and chemical details of the emission itself, as well as the topography, micro-meteorology and land usuage of the receptor area, are all important factors.

Emission Standards

Emission standards, like design standards, specifically indicate amounts of contaminants permitted to enter the atmosphere. Design standards are applied to individual stationary sources. Emission standards are developed for groups of like or identical sources such as automobiles.

Present Ontario automobile regulations incorporate exhaust emission standards for carbon monoxide and hydrocarbons. A similar standard governing the emission of oxides of nitrogen will come into force for the 1973 model year.

Smoke Density Chart



Smoke control is enforced by means of visual observation using a smoke density chart. Number 2 density (40 per cent black) is permitted for not more than 4 minutes in a half-hour period. When starting a new fire, number 3 density (60 per cent black) is permitted for 3 minutes in a 15-minute period. At all other times, the smoke density must not be greater than number 1 (20 per cent black). In cases of equipment failure, permission may be granted to exceed the limitations.

Official use of the chart is restricted to properly trained provincial government officers.

Air Quality Criteria

The major goal of air management in Ontario is the steady improvement of ambient air quality across the province, i.e., the reduction of air contaminant concentrations to desirable levels. Criteria for desirable air quality have been established under the Air Pollution Act for 15 different contaminants.

The criteria for sulphur dioxide are: 0.25 parts per million (p.p.m.) parts of air by volume averaged over a period of one hour;

0.10 p.p.m. averaged over 24 hours; 0.02 p.p.m. averaged over one year.

The criteria for suspended particulate matter are: 90 micrograms per cubic metre of air averaged over a period of 24 hours; a geometric mean of 60 micrograms per cubic metre for a period of one year.

These values are considered as objectives or goals and are used to assess existing air quality, evaluate progress and predicate abatement strategies.

Organization of the Air Management Branch

For administrative purposes, the Air Management Branch has divided the province into seven regions. Each is headed by a regional engineer and sub-divided into districts staffed by qualified engineers and inspectors. Offices are located in 15 cities across the province: Toronto, Hamilton, Peterborough, Welland, Waterloo, London, Windsor, Sarnia, Barrie, Oakville, Kingston, Ottawa, North Bay, Sudbury and Thunder Bay. Head office is in Toronto.

The number of districts and the personnel assigned to them are dependent upon economic activity, population and complexity of local air pollution problems. Total staff numbers approximately 225, excluding central administration personnel. The professional staff consists of 59 engineers, 25 scientists, 9 engineering assistants, 38 technicians and 61 inspectors.

The Air Management Branch contains six operating sections: Abatement, Approvals and Criteria, Air Quality and Meteorology, Automotive Emission Control, Phytotoxicology, Laboratory.

The Abatement Section investigates air pollution complaints, initiates and helps develop abatement programs and keeps check on programs to see that they are functioning efficiently.

The development of an abatement program begins with a complete emission survey of the operations concerned. The owner is then given a written report containing a list of the operations not in compliance with the requirements, recommendations concerning the control measures required and a time limit for compliance. The recommendations do not specify the means of control but rather the limitations to be met.

Should the owner accept the recommendations and time limit, the Minister of Energy and Resources Management issues an Order confirming them. The Order is a legal document and failure to comply can result in prosecution.

If the owner feels that the recommendations are unreasonable, he may request a hearing within 14 days by the Air Pollution Control Advisory Board. The Board consists of representatives from the engineering, medical, urban planning, industry, agriculture and labor fields. After the hearing, the Board advises the Minister whether the recommendations should be confirmed or varied and he issues the Order

in light of the Board's advice.

The Approvals and Criteria Section evaluates the efficiency of proposed air pollution control methods, provides technological support for abatement field officers and establishes criteria for acceptable air quality levels.

Anyone planning to construct a new potential source of air pollution or modify an existing source in Ontario must first obtain a certificate of approval through the section. Failure to do so may result in necessary alterations if an unapproved facility is subsequently found to be in violation of the Air Pollution Control Act, 1967, or its regulations.

Certificates of approval are required for all industrial processes, large fuel burning installations, incinerators, and all commercial and institutional establishments emitting contaminants to the outdoor atmosphere.

Exempt are space heating installations for residential buildings housing three families or less and commercial establishments containing less than 35,000 cubic feet of space. However, corrective action can still be taken under the Air Pollution Control Act if air pollution complaints are received about such sources.

The Air Quality and Meteorology Section is primarily responsible for measuring air quality in Ontario. It also conducts applied research in the air pollution field and helps establish ambient air quality criteria.

The continuous monitoring of air pollutants and meteorological conditions in localized areas is done through a network of over 750 instruments spread across the province. Data is telemetered to Toronto for analysis and the calculation of air pollution indexes.

Pollutants monitored continuously are sulphur dioxide, dust particles, carbon monoxide, hydrocarbons, oxides of nitrogen, hydrogen sulphide, ozone and fluorides. Other contaminants measured on a spot sampling basis include lead, mercury , calcium, iron, magnesium, manganese, zinc, nickel, copper, nitrates, phosphates and sulphates.

The section is responsible for the development of a computerized mathematical air quality model for Metropolitan Toronto. The model consists of an information system containing pertinent facts about pollution sources, a wind generation routine for processing meteorological data and a simulation model by which climatic conditions and sources and amounts of pollution can be related to provide indications of actual air quality.

If fully successful, the model will enable the Air Management Branch to evaluate different abatement strategies for existing pollution sources and predict changes in air quality due to both the construction

of new sources and the implementation of new regulations (e.g., those governing automotive exhaust emissions). Similar models will be developed for other areas of the province.

The Automotive Emission Control Section works to reduce air pollution caused by automobiles, trucks and buses. Regulations governing emissions from automobiles went into effect at the beginning of the 1969 model year. As a result, 1970 automobiles produce only 30 percent of the emissions that come from 1968 models. 1975 automobiles will produce only five to ten per cent of 1968 emission levels.

Heavy duty gasoline and diesel powered vehicles have also been covered by regulations since the beginning of 1970. The section is working closely with the Automotive Transport Association of Ontario in an attempt to reduce excessive emissions from diesel trucks and buses. It is also conducting research into the adoption of anti-pollution devices for older uncontrolled motor vehicles.

The section operates two mobile test laboratories to carry out spot checks on 1969 and newer model cars. These checks indicate whether their pollution control devices are functioning efficiently or have been tampered with or removed. Maximum fine for tampering or removal is $100.00

The Phytotoxicology Section is responsible for determining the degree and extent of air pollution injury to all types of vegetation throughout Ontario. It investigates complaints of economic loss to determine whether injury to plant growth is caused by air pollutants or by other harmful agents such as disease, insects, adverse weather, poor nutrition or mismanagement.

After making an assessment, the section prepares a report which goes to both the complainant and the owner or operator of the air pollution source allegedly responsible for the injury. If the parties concerned cannot reach an agreement privately, they may call on a Board of Negotiation to intervene. If no satisfactory settlement can be reached, court action may follow.

The section maintains a close surveillance of vegetation in areas of concern throughout Ontario. Ecological studies keep it informed of increasing or decreasing vegetation effects in the vicinity of existing pollution sources. Baseline studies are conducted in agricultural or forested areas before new major pollution sources become operational to determine pre-pollution endemic conditions.

The Laboratory Section provides a chemical analytical service to the Air Management Branch. It conducts analysis of air-borne contaminants, vegetation and soil samples, and certain other materials (metal plates, pieces of rubber and nylon) that have been left exposed to the atmosphere for varying lengths of time. Each is analyzed for the effects of corrosive elements.

The need for analysis and measurement has accompanied the development of extensive sampling networks throughout the province and the increased investigation of source emissions and complaints directed to the Branch.

Research is conducted into ways of improving sampling and analysis techniques in order to expand the knowledge spectrum of air pollutants. This research is especially directed at certain harmful contaminants that are difficult or impossible to analyze by conventional monitoring methods.

Inter-Departmental Co-Operation

The work of air pollution control often involves the participation of other provincial government departments and agencies. Common programs and investigations are co-ordinated by the Pollution Control Advisory Committee. The Committee is chaired by the Deputy Minister of Energy and Resources Management. Six departments are represented -- Mines and Northern Affairs, Lands and Forest, Agriculture and Food, Health, Municipal Affairs, Energy and Resources Management -- as well as the Ontario Water Resources Commission.

The Department of Health provides advisory services through a physician on loan to the Air Management Branch. He advises on ambient air quality criteria and investigates specific complaints of health effects. In addition, the Department of Health conducts epidemiological studies.

International Co-Operation

Ontario directly shares an international boundary with three American states. Because of the problems of transboundary air pollution, the provincial government is involved in various programs at both federal and province-state levels, much of it through the International Joint Commission. Established by the Canadian and American governments, the Commission does not have any regulatory powers but does conduct comprehensive investigations and recommend corrective actions.

Various state and provincial personnel become involved in the Commission's work. A recent example is a study completed in January, 1971, on air pollution problems in the Sarnia-Port Huron and Windsor-Detroit areas of Ontario and Michigan.

Air Pollution Index and Alert System

A significant aspect of Ontario's air management program is its Air Pollution Index and Alert System. The Index was established to give warning of, and to prevent the adverse effects of air pollution build-ups during prolonged periods of stagnant weather. It went into operation in Toronto in March, 1970; Hamilton in June, 1970; Sudbury in January, 1971; Windsor in March, 1971. The Index network is gradually being expanded to other major centres in the province.

The Index is based upon continuous measurements of sulphur dioxide and suspended particulate matter, Ontario's two major air

pollutants. Both have been found in high concentrations during severe air pollution episodes in other parts of the world and extensive data is available relating severity of health effects to degree of pollution as measured by their presence.

The structure of the index is a numerical scale beginning at 0. Readings below 32 are considered acceptable, indicating concentrations of sulphur dioxide and suspended particulate matter that should have little or no effect on human health. At 58, people with chronic respiratory disease may be affected. At 100, prolonged conditions could have mild effects on healthy people and serious effects on those with severe cardiac or respiratory disease.

The alert system functions at four index levels -- 32 (Advisory Level), 50 (First Alert), 75 (Second Alert), 100 (Air Pollution Episode Threshold Level).

At 32, if meteorological conditions are expected to remain unfavorable for at least six more hours, owners of major sources of air pollution sources may be advised to prepare for possible curtailment of their operations. At 50 and 75, under continuing, adverse meteorological conditions, they can be ordered to curtail them.

At 100, the Minister of Energy and Resources Management can order all sources of air pollution not essential to public health or safety to cease operations. A reading of 100, however, is unlikely to be reached becuase of previous provisions for curtailment at lower index levels.

The highest Toronto index reading, based upon available figures, would have occurred in Toronto between November 30 and December 4, 1962. The index would have reached a peak of 155 during the evening of December 1, and 125 during the early morning hours of December 4. The average reading over this four day period would have been 95.

The most significant aspect of this particular pollution build-up was a dense smog which caused that year's Grey Cup game to be played on two separate days. There was no recorded incresase, however, in hospital admissions of people with respiratory ailments during this period, an indication of the margin of safety built into the index.

Financial Assistance For Air Pollution Control Programs

There are several ways in which companies, institutions and municipalities can obtain financial assistance for the installation of air pollution control equipment.

They can apply for grants up to the amount of the provincial sales tax paid on the equipment, obtain Ontario Development Corporation loans, receive certain federal sales tax exemptions and take advantage of accelerated capital cost allowances.

Grants are also available through the Department of Energy and Resources Management to universities and other organizations for research and training of persons in the field of air pollution, and to

municipalities to assist in the administration and enforcement of air pollution by-laws. The 1970 research budget was $318,000.

Suggested Code for Livestock Buildings and Animal Wastes

"A Suggested Code of Practice for the Establishment of New Livestock Buildings, Renovation or Expansion of Existing Buildings, and Disposal of Animal Wastes" was prepared in 1970 by the Departments of Energy and Resources Management, Agriculture and Food.

The Code is only a recommended guideline, but one that Ontario farmers are being urged to follow. Because of a population increase in farming areas and more intensive livestock and poultry production, greater animal wastes are being produced, often without adequate provision for disposal. As a result, serious odor problems have developed, affecting both rural and urban people.

The Code provides fair and satisfactory measures for dealing with the problem. Key measures stress the need for enough land on which to dispose of wastes, sufficient waste storage capacity (e.g. underground tanks), and adequate distances between livestock and poultry buildings and neighbouring dwellings.

Farmers following the Code can invite inspection of their premises. If they are considered to be operating within its provisions they receive a letter of approbation to that effect.

In Conclusion

Air pollution remains a serious problem in certain parts of Ontario. A considerable amount of progress has been and is being made, however, and major improvements are forthcoming. Within the next few years, virtually all sources of air pollution in the province will be under control, emitting either no contaminants at all or contaminants at acceptable levels of concentration. When this degree of control has been achieved, pollution build-ups will occur only during prolonged periods of stagnant weather.

In the meantime, everyone can do something about air pollution by:

1. burning wasteless fuels.
2. keeping cars well tuned.
3. turning off car engines when forced to wait for more than a minute or two.
4. walking or using public transportation rather than a car.
5. using hand lawn mowers.
6. not burning rubbish and leaves in open fires.

Open fires are a particular problem. A large percentage of the Branch's inspection time is taken up with their control -- time that could be put to much better use regulating more serious problems. In this area alone, therefore, there are significant opportunities for individuals to contribute to the control of air pollution. Much could be accomplished if everyone took advantage of them.

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An Introduction to Air Pollution and Its Control in Ontario

Ontario

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Minister

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Deputy Minister

AN INTRODUCTION TO AIR POLLUTION AND ITS CONTROL IN ONTARIO

Air pollution control is a matter of vital concern to us all. Each of us, on average, breathes 22,000 times a day, taking in about 35 pounds of air in the process. It is our main link with life, far exceeding our dependence on food and water. An adult might live six weeks without food, three days without water, but only minutes without air. Its quality must be protected.

What Is Air Pollution?

In simple terms, air pollution exists when certain substances are present in the atmosphere in sufficient concentrations that they adversely affect the environment.

As defined in Ontario's Air Pollution Control Act, 1967, air pollution is "... the presence in the outdoor atmosphere of any air contaminant or contaminants in quantities that may cause discomfort to or endanger the health or safety of persons, or that may cause injury or damage to property or to plant or animal life or that may interfere with visibility or the normal conduct of transport or business.

Historical Background and First Attempts at Control

Air pollution is not a new problem. It is caused by a variety of natural phenomena as well as by human activities and has been present since the earth began.

Natural air pollution results from volcanic eruptions, earthquakes, forest fires and even simple wind action. Bacteria, pollen and salt crystals (the last from the surfaces of large bodies of salt water) can be carried by wind, for example, for great distances before being deposited. Sea-water salt in fact has been found in the prairie provinces.

Man began contributing to air pollution with his first fire and he steadily continued to do so during his development through the ages of fire, copper, bronze, iron and steel down to the present age of atomic power and space travel. Even so, all but two air pollutants are still produced in far greater tonnages by natural processes than by modern

industry. Man outdoes nature only in the production of sulphur dioxide and carbon monoxide.

British recorded history shows how long air pollution has been a problem in that country.

In 1257, the smoke of Nottingham was so bad that Queen Eleanor, who was staying there while Henry III led an expedition into Wales, was compelled to move to Tutbury.

In 1306, Edward I issued a royal proclamation prohibiting the use of coal in certain furnaces. Punishment for the first offence was a fine; for the second, demolition of the furnace; for the third, execution. One such execution actually took place.

In 1661, coal smoke was so bad in London that the diarist John Evelyn, in writing about it stated, "... the weary Traveller, at many miles distance, sooner smells, than sees the City."

Initially, air polluting activities were limited to small settlements and towns and they were treated as individual smoke and odor problems because only those people living close to actual sources were affected. With the coming of the Industrial Revolution, however, the situation rapidly changed. Cities grew and air pollution incidents increased in both frequency and complexity resulting in total pollution of entire metropolitan air spaces.

In England, the smoke problem began to be attacked on a community basis in the 19th century. The first anti-smoke ordinance was adopted in 1857. In the United States, the first such law was put into force in Chicago in 1881. In Canada, a Toronto by-law was passed in 1907.

In the 20th century, the resources of science and technology began to be applied more fully to the control of municipal air pollution as greater knowledge of the nature and control of air pollution started to emerge.

In the early part of the century, control programs were designed to control visible emissions, primarily smoke. It is only in the last 20 years that legislation has been passed concerning invisible air pollution. (1) During this period, the problem has commanded the attention of professionals from many specialized disciplines -- engineering, law, public administration, economics, medicine and numerous areas of pure science.

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(1) When the term "air pollution" is used, it is usually done so with regard to smoke pouring out of a chimney. Actually, the smoking chimney is only one source of air pollution. There are many others producing both visible and invisible contaminants. Carbon monoxide is an obvious example of invisible pollution. Another is cigarette smoke. Its gases and particles remain in the air long after disappearing from actual view.

Sources of Air Pollution

Air pollution is a major by-product of a civilization that has become dependent upon industrial technology for survival. Our age is one of complex production techniques, sophisticated forms of transportation, mass communication, rapid distribution systems for the delivery of raw materials and manufactured products, centralized energy and heat sources, intricate urban structures. All aspects are involved in the production of air pollution which results from three basic processes:

1. Combustion

2. Vaporization

3. Mechanical attrition

Combustion

The combustion of fossil fuels and waste materials for heat, steam and electrical energy is required for warmth, metal melting, motive power, food processing, incineration of waste materials, baking, tempering, curing and many other operations. The products of combustion -- smoke and gases -- comprise what are known as "contaminant plumes," the familiar trademarks of all industrial areas.

Vaporization

Vaporization, or volatilization, is a by-product of many chemical and manufacturing operations which induce physical changes in substances through the application of heat and pressure, thereby causing some component materials to vaporize into the atmosphere.

Vaporization includes the evaporation of volatile materials at normal atmospheric temperatures and pressures; fuming, as a result of induced temperatures; and decomposition of organic materials due to natural processes. Materials that evaporate at normal atmospheric temperatures and pressures include petroleum derivatives such as gasoline, fuel oil, paint and cleaning solvents.

Fuming includes both volatilization and condensation. It takes place in acid manufacturing and handling, and in metal melting operations where molten metal liquids are first volatilized to the gas state and then condensed to dusts by rapid cooling. Decomposition is associated with the handling of highly organic compounds or animal tissue with nitrogenous or sulphurous contents.

Mechanical Attrition

Mechanical attrition includes crushing, grinding, drilling, demolishing, mixing, batching, blending, sweeping, sanding, cutting, pulverizing, spraying, atomizing, etc., all of which either directly or indirectly disperse particulates in the form of dusts or mists into the atmosphere. These activities are everyday aspects of modern life and industry.

Types of Air Pollution

Air pollution consists of either one or a combination of the following physical states:

1. Aerosols and particulates (mists and dusts)

2. Organic gases

3. Inorganic gases

1. Aerosols and Particulates

The diameters of contaminant particles emitted from man-made sources vary greatly in size from 1,000 microns (the size of raindrops) to substantially less than one micron. (The micron is a microscopic unit measure equivalent to 1/1,000 of a millimetre, or 1/25,000 of an inch.) Cigarette smoke particles range in size from 0.01 to 0.5 micron. Particles smaller than 10 microns tend to remain suspended in air. Larger particles tend to settle upon available surfaces.

Aerosols are usually taken to mean particles which range in size from 10 microns to something less than 0.01 micron. Most aerosols are considered to be less than 1 micron in diameter.

Particulate matter is responsible for two basic air pollution effects:

1. Soiling, corrosion, injury to clothing, property and crops as a result of deposition.

2. Adhesion of particulate matter to respiratory tissues with possible physiological impairment or damage. Particulate matter may include toxic substances, possibly carcinogens and radioactive materials.

Aerosols tend to remain suspended permanently in the air. They are usually emitted either in aerosol form or evolve from the fracturing or decomposition of large particulates. They also form in the air from the condensation and nucleation of gaseous contaminants. They may be organic or inorganic in composition, and either liquid or solid.

The smaller the aerosols, the more they behave like a gas. Aerosols, therefore, are not as readily deposited as the particulates and may be inhaled and exhaled with air. Aerosols are also important because of their ability to reduce visibility through the process of light scattering.

2. Organic Gases

Organic gases are hydrogen-carbon compounds and their derivatives. They include all classes of hydrocarbons (olefins, paraffins and

aromatics) and the derivatives formed when hydrogen is replaced by oxygen, halogens, nitro or other substituent groups.

The principal origin of hydrocarbons is petroleum. Hydrocarbons and their derivatives are released to the atmosphere during the refining of petroleum and the transfer, storage and use of petroleum products (fuels, lubricants and solvents). They are also formed in the atmosphere due to certain photochemical reactions.

The most important source of hydrocarbon emission is the gasoline-fuelled motor vehicle, especially in heavily populated areas. The other major class of hydrocarbon contributor consists of industrial and commercial users of organic solvents. They and their counterparts in the petroleum industry account for 98% of all hydrocarbon emissions.

Hydrocarbons and their derivatives are important because of their role in the production of photochemical smog. Most reactive are the olefins (unsaturated hydrocarbons). They can react with nitrogen dioxide to produce visibility-reducing aerosols and oxidants (primarily ozone) causing plant damage and eye irritation.

Paraffins (saturated hydrocarbons) and aromatic hydrocarbons can also react with nitrogen dioxide to produce a similar variety of irritating effects. Hydrocarbon derivatives produced by photochemical reactions include aldehydes, ketones, and nitro-substituted organics that in turn react to worsen smog effects.

3. Inorganic Gases

Major inorganic gases are oxides of nitrogen, oxides of sulphur and carbon monoxide. Of less importance with regard to air pollution are ammonia, hydrogen sulphide and chlorine. Principal source of the oxides is fuel combustion --industrial, commercial and domestic for purposes of transportation, space heating and power generation.

Oxides of nitrogen: There are many oxides of nitrogen but only nitric oxide (NO) and nitrogen dioxide (NO_2) are important as air contaminants. Nitric oxide is formed when atmospheric nitrogen is oxidized during fuel combustion in automobiles, incinerators and industrial furnaces. The amounts produced are in direct proportion to fuel consumption, increasing tremendously at high temperatures.

Once in the atmosphere, nitric oxide is then able in the presence of sunlight to combine with available atmospheric oxygen to form nitrogen dioxide, one of the major ingredients, as mentioned above of photochemical smog. Oxides of nitrogen have increased in quantity lately, largely due to the greater compression ratios and engine temperatures of late model motor vehicles.

Oxides of sulphur: Only two oxides of sulphur -- sulphur dioxide (SO_2) and sulphur trioxide (SO_3) -- are classified as air contaminants. They are formed primarily during the combustion of fuels that contain sulphur (e.g., coal and oil). The amounts produced, therefore, are

direct functions of fuel sulphur content and total fuel consumption. Normally, sulphur dioxide is produced in far greater quantities than sulphur trioxide. The latter is formed only under rather unusual conditions.

Gaseous oxides of sulphur are significant because of their toxicity. They have been associated with illness arising from many severe air pollution episodes although the exact relationship, even at concentrations found in the most heavily industrialized community, is still ill-defined.

Each oxide can combine with water in the air to form toxic acid aerosols that corrode metal surfaces, fabrics and plant leaves. Sulphur dioxide, in particular, causes a characteristic type of vegetation damage whereby portions of leaves are bleached in a specific pattern. In concentrations as small as 5ppm., sulphur dioxide is irritating to the eyes and respiratory system. It is colorless with a characteristically pungent suffocating odor.

Carbon monoxide: Carbon monoxide (CO) results from the incomplete combustion of carbonaceous fuel. Automobiles are the principal source, contributing as much as 97% of the total amount in a large metropolitan area. The exhaust from an individual car is one to five per cent carbon monoxide depending upon carburetor adjustment. Although produced in enormous quantities throughout the world, carbon monoxide forms only .00001 per cent of the atmosphere. It is presumed that most of it is oxidized to carbon dioxide (CO_2).

Carbon monoxide is poisonous to man and animals. In suitable concentrations, it acts as an asphyxiant interfering with the blood's ability to carry and release oxygen. Initial symptoms are slight headache and shortness of breath. In sufficient concentrations, it is, of course, fatal.

In general, toxicologists hold that concentrations of carbon monoxide would have to exceed 500 ppm for at least one hour before a detectable effect upon human health is produced. Carbon monoxide has been detected in urban atmospheres at concentrations ranging from substantially 0 to 150 ppm. Greater concentrations have occasionally been measured in confined spaces such as tunnels and large, poorly ventilated garages. As yet, atmospheric concentrations have not been linked to fatalities.

Miscellaneous Inorganic Gases: Ammonia, hydrogen sulphide, chlorine, fluorine and fluorides are normally detectable in only trace quantities in the atmosphere but all are toxice in small to moderate concentrations. The first three have unpleasant odors.

Hydrogen sulphide can cause discoloration of certain kinds of paint. Ammonia can discolor certain fabric dyes and is corrosive to copper, brass, aluminum and zinc. Chlorine can discolor certain fabric dyes. Fluorine and fluorides, especially hydrogen fluoride, are highly toxic and corrosive. They can cause damage to vegetation, and illness and injury to humans and animals.

Effects of Air Pollution

As air pollution increases, certain effects become apparent. Visibility is reduced, vegetation is injured, property and clothing are soiled and, most vital of all, human health is affected.

Visibility Reduction

Reduction in visibility is due to the concentration of aerosols in the atmosphere. There are two basic effects:

1. Sky darkening

2. Haziness (light scattering)

Sky darkening is the physical obstruction of sky illumination due to clouds of contaminants or plumes of smoke and fumes.

Haziness is the alteration of sky illumination due to light scattering. The blue color of the sky is the result of sunlight being scattered by molecules of atmospheric gases. Similarly, the color of the sky can be altered by pollution hazes. Type and degree of alteration depends upon the size of aerosols present relative to light wave length. Aerosols 0.4 to 0.9 microns in diameter are most effective in light scattering.

Visibility reduction is an indication of pollution accumulation and its measurement is one way in which pollution intensity can be determined. Visibility records can be used to show daily, weekly, monthly and yearly variations. They reflect not only weather variations but also changes in industrial practices and the effects of pollution control procedures.

As the sky is darkened, either by normal cloud or pollution effects, the amount of available sunlight reaching the ground is reduced. As sunlight is essential to human and plant life, its obstruction due to any cause can be a serious matter if it occurs often or for prolonged periods.

Vegetation Injury

Injury to crops and trees resulting from air pollution has been clearly established. It can range from visible markings on foliage to reduced growth and yield to premature death of plant life. The ensuing visual and economic consequences can at times be disastrous. Injury to crops possessing marketable foliage such as lettuce or tobacco can result in especially high losses.

Vegetation injury often serves as a warning to man of the presence of toxicants that may also affect human health and poison foraging cattle. In addition, it can sometimes be used as an indicator of the chemical reactivity of the air.

Vegetation in Ontario suspected or known to have been injured by air pollutants include ornamental flowers, garden fruits and vegetables, stored vegetables, greenhouse chrysanthemums and roses, farm crops (white beans, tomatoes, green onions, winter wheat, oats, and corn), animal pastures and cured hay, and fruit and forest trees.

Suspected air pollutants and those ascertained as having caused vegetation injury include fluorides, sulphur dioxide, oxidants, boron, lead chlorine, hydrogen chloride, liquefied gases, chromium, nickel, salt spray, urea, nitrogen dioxide, ammonia, cement dust, magnesium-lime dust, flyash and detergents. Any pollutant that injures vegetation is known as a phytotoxicant.

Injury to foliage may become visible in a short time and take the form of necrotic lesions (dead tissue) or it can develop slowly and become manifest as a yellowing or chlorosis of the leaf. There may be a reduction in growth of various portions of a plant or a loss in reproductive parts or in yield. Plants may be killed outright but they usually do not succumb until they have suffered injury perennially.

Injury may not be visible externally occurring subcellularly in cell membranes and chloroplasts (plant organelles where photosynthesis takes place). The plants may suffer physiologically due to an upset in the rate of photosynthesis, respiration or transpiration.

The symptoms of injury caused by phytotoxicants can be very similar to those of injuries caused by disease, insects, adverse weather, poor nutrition or mismanagement. All suspected cases require careful diagnosis by specialists.

The protection of plants from the adverse effects of aerial phytotoxicants cannot be carried out in exactly the same manner as is possible with disease-causing, organic reproductive bodies. A pollution-diseased plant cannot infect another plant; thus there is no need for a quarantine or for eradication of the affected plants. In certain instances, sprays and dusts have protected plants from air pollution injury. The development of resistant varieties holds some promise. The best control method, however, is to reduce the concentrations of noxious pollutants at their sources.

Soiling and Property Damage

One of the first material effects of air pollution is the soiling of clothing, buildings and properties. Air pollution has a direct influence on the cost of cleaning and laundering, the marketability of merchandise and the cleaning of buildings. It is responsible for considerable economic loss.

Property damage is usually of a cumulative nature. It tends to shorten the durability of materials exposed to the atmosphere. It is generally caused by the interaction of contaminants with the surface or protective coatings of materials.

Typical effects are metal corrosion, stone and masonry deterioration excessive cracking of rubber tires and damaged automobile paintwork.

Health Effects

Effects on human health have been most dramatic during so-called air pollution "episodes." These are fortunately rare. They occur when stagnant weather conditions allow a concentration of air pollutants to build up over a period of several days. At such times, people with severe chronic respiratory disease are greatly affected and many excess deaths can occur.

Serious pollution episodes have occurred in various parts of the world including the Meuse Valley of Belgium; Donora, Pennsylvania; New York City; London, England. Of these, the Donora and London episodes provide particularly dramatic evidence of the effects of air pollution.

In Donora, an industrial community located in a deep valley 30 miles south of Pittsburgh, thousands of people became ill, several hundred were hospitalized and 20 died when air pollutants from mills, smelters and acid plants accumulated during a calm period of weather in October, 1948 and did not disperse for four days.

In London, a much more serious episode, perhaps the worst in history, occurred in December, 1952. Again, during calm weather, air pollution became so concentrated that 4,000 deaths resulted from various respiratory diseases both during and after the episode.

The effect of day-to-day exposure to lower concentrations of air pollution is very difficult to assess. Some individuals are relatively susceptible, others less so. On the whole, people who live in industrial centres have an increased chance of getting certain diseases of the respiratory system.

Some forms of air pollution are more annoying than harmful. This is true of many unpleasant odors. Where the main source of pollution is the automobile, the air may cause the eyes to tear and the throat to be irritated without having any apparent lasting effect. Much research is still required to determine the real long term effects of exposure to polluted air.

Meteorology and Air Pollution

Meteorological factors greatly effect the amount of pollution present in the atmosphere. Temperature and solar radiation, by their influence on the amount of space heating required, affect the quantities of pollutant emitted. Sunshine is required for the photochemical production of oxidants that form smog.

Wind velocity, turbulence and stability affect the transport, dilution and dispersion of pollutants. Rainfall has a scavenging effect by washing out particles in the atmosphere. Finally, humidity is a frequent and important factor in determining the effect of pollutant concentrations on property, vegetation and health.

Meteorological parameters having the most important influence on the diffusion of pollutants in the atmosphere are wind direction and speed, turbulence, temperature and stability.

Wind

Wind is air in motion in three dimensions. Only the horizontal component, however, is usually considered in terms of direction and speed.

Wind direction indicates direction of travel of pollutants. It is a very important factor in predicting the air pollution potential of an area in which the principal pollutant sources are high stack emitters located close together. Wind direction is less important where low level emitters (low smoke stacks, automobiles etc.) cause most of the pollution.

Expected persistence of wind direction, related to topographic features and location of receptors, must also be considered both when forecasting air pollution potential and selecting sites for plants. Topographical features such as valleys cause winds to persist in certain directions at much greater frequencies than others. Obviously, large industries should not be located in such areas.

Wind speed determines the travel time of pollutants from a source to a receptor. Wind speed also has a dilution effect. Pollutant concentrations downwind from ground level sources are inversely proportional to wind speed.

This dilution effect is not true for hot emissions from high stack sources. In these instances, an increase in wind speed lowers the plume rise, thus tending (up to a point) to increase ground level concentrations. There is a "critical wind speed" for each stack design at which concentrations downstream reach a maximum.

Turbulence

High frequency fluctuations in the wind are known as turbulence and they occur both vertically and horizontally. These random motions

are responsible for the movement and diffusion of pollutants about the mean wind path.

Mechanical turbulence is caused by roughness of terrain -- trees, shrubs, buildings, etc. Thermal turbulence is due to the earth's surface being heated by the sun. Thermal eddies develop as the air, heating up at lower levels first, becomes less dense and rises.

Temperature

The temperature of the lower region of the atmosphere (surface to 2 km.) can either decrease or increase with height depending on the character of the underlying surface and the radiation at the surface. During the day, temperature usually decreases with height. As a result, the warmer air near to the ground and the pollutants emitted into it rise and disperse high into the atmosphere. Concentrations of pollutants in the lower layers of the atmosphere are relatively low.

When the reverse occurs and temperature increases with height, a temperature inversion is said to exist. An inversion inhibits the rise and dispersion of pollutants emitted in the atmosphere. Thus, when pollutants are emitted near the ground during an inversion, they remain and cause high concentrations to develop.

The Automobile and Air Pollution

The automobile is a major source of air pollution. In addition to carbon dioxide and water vapour, its exhaust emissions contain carbon monoxide, oxides of nitrogen, unburned hydrocarbons and lead.

Automotive pollutants result from the incomplete burning of fuel. When there is sufficient oxygen, hydrocarbon fuel is completely converted into carbon dioxide and water vapor. Incomplete combustion also produces carbon monoxide, hydrocarbons and oxides of nitrogen.

Incomplete combustion can occur for various reasons -- poor mixing of air and fuel, short combustion time, quenching of the combustion process near a cool chamber wall, dead space where the combustion flame can not penetrate.

Some of these problems can be reduced or eliminated by fine tuning of the carburetor and timing mechanism, by heating the air or fuel prior to mixing, or replacing the standard carburetor with a fuel injection system.

Crankcase emissions are eliminated by using a PCV (positive crankcase ventilation) valve that feeds crankcase vapors back to the air intake system to be burned in the combustion chamber. Gasoline evaporating through either the fuel tank breather tube or carburetor can be greatly reduced by terminating such tubes and other outlets with an activated charcoal filter that absorbs escaping vapors.

A catalytic muffler containing certain types of catalysts can be used to oxidize toxic gases in the exhaust. Due to the poisoning effect that lead has on the catalyst, however, the system can only be used with gaseous fuels, diesel fuel or unleaded gasoline.

Possible alternatives to the internal combustion engine are an electric power source, a modified steam engine and the gas turbine. Of special interest at present is the gasoline-electric hybrid that can be run on either gasoline or electric power.

Air Pollution Control In Ontario

Action against air pollution in Ontario began, as in most other jurisdictions, at the municipal level with the passing of local by-laws restricting smoke emissions.

In 1955, the Ontario government appointed a select committee to study the problem of air pollution and its control. As a result of the committee's report, the province passed its first Air Pollution Control Act in 1958. It delegated the control of air pollution to municipalities but widened the scope considerably to provide for the control of all sources of air pollution.

Actual provincial involvement under the 1958 legislation was purely advisory. In 1963, however, the Act was amended to give the province a more direct role. It undertook the approval of new sources of industrial air pollution, instituted a training program for municipal inspectors and established a program of financial assistance.

Attempts to stimulate air pollution control activity at the municipal level proved largely unsuccessful. Only four municipalities employed full-time staff. During the middle 1960's, it became readily apparent that serious headway could only be made by a centralized authority.

The province assumed full responsibility for the control of air pollution with the passing of the Air Pollution Control Act, 1967. The Act became effective January 2, 1968, and the Air Pollution Control Service of the Department of Health was named enforcement agency. In 1969, the Service was transferred to the Department of Energy and Resources Management Branch and renamed the Air Management Branch.

Scope of Air Pollution Control Act, 1967

Under the Act, the Ontario Government, through the Minister of Energy and Resources Management and the Air Management Branch, possesses broad powers allowing it to:

1. conduct air quality and meteorological studies and monitoring programs.

2. establish acceptable air quality levels.

3. inspect and regulate all sources of air pollution.

4. order, after investigation, the discontinuance of the discharge of any air contaminant. This action is reserved for unusual cases where such a discharge creates an immediate and serious danger to public health, and where a delay in following the usual procedures under the Act would prejudicially affect the public.

5. initiate legal action for violation of either a regulation made under the Act, or of a Minister's Order issued to correct a pollution condition. Maximum fine for an individual is $2,000; for a corporation, $5,000 on first conviction and $10,000 on second conviction. Each day that a violation occurs constitutes a separate offence.

Numerous regulations have been made under the Act. Of special importance are those regulations that established an air pollution index, standards for emitted contaminants, criteria for desirable ambient air quality, standards governing the sulphur content of fuels sold in Metropolitan Toronto and air pollution emission standards for motor vehicles, ferrous foundries and asphalt paving plants.

Non-legislated guidelines include criteria for the design and operation of incinerators and conical wood waste burners and a suggested code of practice covering the establishment of livestock buildings and the disposal of animal wastes.

Controlling Stationary Sources of Air Pollution

Prior to the 1967 Act, new industrial sources of air pollution, as already mentioned, had been subject to pre-construction government approval since 1963. In January, 1968, all new stationary sources of air pollution became subject to such approval.

At the same time, surveys were undertaken across the province to locate and assess existing sources of air pollution for which abatement programs began to be developed. As of April, 1971, most large and many smaller stationary sources of air pollution in Ontario have had or are about to have abatement programs established by which their polluting emissions are being either eliminated or reduced to acceptable levels.

Controlling Mobile Sources of Air Pollution

Mobile sources present a different control problem. Motor vehicles (automobiles, trucks, buses) come under provincial jurisdiction; ships, trains and aircraft do not.

Controls for certain classes of motor vehicles were brought into force at the beginning of the 1969 model year. Based upon regulations adopted first in California and later for all of the United States, they have been broadened in scope and made more stringent each successive year.

All aspects of ship, train and aircraft operation come under federal jurisdiction. The Air Management Branch can and does, however, enforce existing federal provisions concerning air pollution from these sources.

Smoke emissions from ships in Canadian waters are regulated under the Canada Shipping Act. Smoke emissions from locomotives and other railway property are regulated by Canada General Order O-26 issued by

the Board of Transport Commissioners for Canada. No regulations have been developed to control aircraft exhausts.

Limiting Air Contaminant Emissions: Design Standards

When the emission of an air contaminant cannot be entirely prevented from a new stationary source of air pollution or eliminated from an existing one, its amount can still be limited to a level that will not be harmful to either humans, animals, vegetation or property.

This is done by applying what are known as design standards to a source. It involves (1) calculating what the subsequent concentration of an emitted contaminant will be at point of contact with an object that could be adversely affected by it, and (2) comparing that concentration with the standard or maximum concentration allowed for the contaminant. If the calculated concentration is too high, modifications become necessary to reduce the amount of contaminant that is being or will be emitted at the source.

In certain instances, when there is no practical method of sufficiently reducing the contaminant at source, a tall stack will be permitted to disperse it over a wider area, thereby reducing ground level concentrations. Dispersion, however, is considered an interim measure only. The goal is elimination of pollutants at their source.

The point of contact mentioned above is referred to as the "point of impingement". It can occur at ground level itself or above ground (e.g., the side of a building). Concentration figures at point of impingement are averages calculated for periods of 30 minutes. The maximum concentration allowed for a given contaminant is well below that at which adverse effects would actually occur.

Maximum allowable concentrations at point of impingement have been established for 20 different contaminants: ammonia, beryllium, bromine, cadmium oxide, carbon bisulphide, carbon monoxide, chlorine, dustfall, fluorides, hydrogen chloride, hydrogen cyanide, hydrogen sulphide, iron, lead, lime, nitric acid, nitrogen oxides, silver, sulphur dioxide, suspended particulate matter. Tentative standards are set when necessary for other contaminants. They are incorporated into regulations when their validity has been fully established.

The maximum allowable concentration of sulphur dioxide at point of impingement is 0.3 parts per one million parts of air by volume averaged over a period of 30 minutes. The maximum allowable concentration of suspended particulate matter at point of impingement is 100 micrograms per cubic metre of air averaged over a period of 30 minutes.

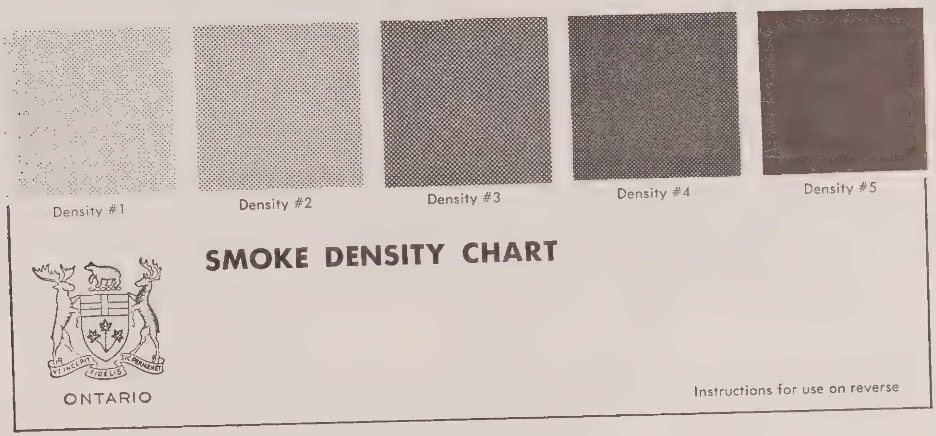
The calculation of a contaminant's concentration at a given point away from its source is a complex procedure beginning with a full evaluation of the equipment and processes involved to determine the contaminant's emission rate to the atmosphere (usually through a stack). When the emission rate is known, the concentration at point of impingement can be calculated. The physical and chemical details of the emission itself, as well as the topography, micro-meteorology and land usuage of the receptor area, are all important factors.

Emission Standards

Emission standards, like design standards, specifically indicate amounts of contaminants permitted to enter the atmosphere. Design standards are applied to individual stationary sources. Emission standards are developed for groups of like or identical sources such as automobiles.

Present Ontario automobile regulations incorporate exhaust emission standards for carbon monoxide and hydrocarbons. A similar standard governing the emission of oxides of nitrogen will come into force for the 1973 model year.

Smoke Density Chart



Smoke control is enforced by means of visual observation using a smoke density chart. Number 2 density (40 per cent black) is permitted for not more than 4 minutes in a half-hour period. When starting a new fire, number 3 density (60 per cent black) is permitted for 3 minutes in a 15-minute period. At all other times, the smoke density must not be greater than number 1 (20 per cent black). In cases of equipment failure, permission may be granted to exceed the limitations.

Official use of the chart is restricted to properly trained provincial government officers.

Air Quality Criteria

The major goal of air management in Ontario is the steady improvement of ambient air quality across the province, i.e., the reduction of air contaminant concentrations to desirable levels. Criteria for desirable air quality have been established under the Air Pollution Act for 15 different contaminants.

The criteria for sulphur dioxide are: 0.25 parts per million (p.p.m.) parts of air by volume averaged over a period of one hour;

0.10 p.p.m. averaged over 24 hours; 0.02 p.p.m. averaged over one year.

The criteria for suspended particulate matter are: 90 micrograms per cubic metre of air averaged over a period of 24 hours; a geometric mean of 60 micrograms per cubic metre for a period of one year.

These values are considered as objectives or goals and are used to assess existing air quality, evaluate progress and predicate abatement strategies.

Organization of the Air Management Branch

For administrative purposes, the Air Management Branch has divided the province into seven regions. Each is headed by a regional engineer and sub-divided into districts staffed by qualified engineers and inspectors. Offices are located in 15 cities across the province: Toronto, Hamilton, Peterborough, Welland, Waterloo, London, Windsor, Sarnia, Barrie, Oakville, Kingston, Ottawa, North Bay, Sudbury and Thunder Bay. Head office is in Toronto.

The number of districts and the personnel assigned to them are dependent upon economic activity, population and complexity of local air pollution problems. Total staff numbers approximately 225, excluding central administration personnel. The professional staff consists of 59 engineers, 25 scientists, 9 engineering assistants, 38 technicians and 61 inspectors.

The Air Management Branch contains six operating sections: Abatement, Approvals and Criteria, Air Quality and Meteorology, Automotive Emission Control, Phytotoxicology, Laboratory.

The Abatement Section investigates air pollution complaints; records and collects evidence to institute legal action against polluters; initiates and helps develop abatement programs, and keeps check on programs to see that they are functioning efficiently.

The development of an abatement program begins with a complete emission survey of the operations concerned. Surveys may be informal to assist a company in determining the nature, cause and extent of emissions as a step toward corrective action. They may also be formalized as a comprehensive survey under Section 83 of the Environmental Protection Act, 1971, which may be followed by the issue of a Control Order by the Director of the Air Management Branch. The Order is a legal document and failure to comply can result in prosecution.

A person to whom an Order of the Director is directed may, within fifteen days, request a hearing by the Environmental Appeal Board. The Board consists of representatives from the engineering, medical, urban planning, industrial, agricultural and labour fields. The Board may confirm, alter or revoke the Order. Provision is also made for a right of appeal, after the Board's decision has been made known, to the county court and to the Minister of the Environment.

The Approvals and Criteria Section evaluates the efficiency of proposed air pollution control methods, provides technological support for abatement field officers and establishes criteria for acceptable air quality levels.

Anyone planning to construct a new potential source of air pollution or modify an existing source in Ontario must first obtain a certificate of approval through the section. Failure to do so may result in necessary alterations if an unapproved facility is subsequently found to be in violation of the Air Pollution Control Act, 1967, or its regulations.

Certificates of approval are required for all industrial processes, large fuel burning installations, incinerators, and all commercial and institutional establishments emitting contaminants to the outdoor atmosphere.

Exempt are space heating installations for residential buildings housing three families or less and commercial establishments containing less than 35,000 cubic feet of space. However, corrective action can still be taken under the Air Pollution Control Act if air pollution complaints are received about such sources.

The Air Quality and Meteorology Section is primarily responsible for measuring air quality in Ontario. It also conducts applied research in the air pollution field and helps establish ambient air quality criteria.

The continuous monitoring of air pollutants and meteorological conditions in localized areas is done through a network of about 900 instruments spread across the province. Data is telemetered to Toronto for analysis and the calculation of air pollution indexes.

Pollutants monitored continuously are sulphur dioxide, dust particles, carbon monoxide, hydrocarbons, oxides of nitrogen, hydrogen sulphide, ozone and fluorides. Other contaminants measured on a spot sampling basis include lead, mercury, calcium, iron, magnesium, manganese, zinc, nickel, copper, nitrates, phosphates and sulphates.

The section was responsible for the development of a computerized mathematical air quality model for Metropolitan Toronto. The model consists of an information system containing pertinent facts about pollution sources, a wind generation routine for processing meteorological data and a simulation model by which climatic conditions and sources and amounts of pollution can be related to provide indications of actual air quality.

The model enables the Air Management Branch to evaluate different abatement strategies for existing pollution sources and predict changes in air quality due to both the construction of new sources and the implementation of new regulations (e.g., those governing automotive exhaust emissions). Similar models are being developed for other areas of the province.

The Automotive Emission Control Section works to reduce air pollution caused by automobiles, trucks and buses. Regulations governing emissions from automobiles went into effect at the beginning of the 1969 model year. As a result, 1970 automobiles produce only 30 percent of the emissions that come from 1968 models. 1975 automobiles will produce only five to ten per cent of 1968 emission levels.

Heavy duty gasoline and diesel powered vehicles have also been covered by regulations since the beginning of 1970. The section is working closely with the Automotive Transport Association of Ontario in an attempt to reduce excessive emissions from diesel trucks and buses. It is also conducting research into the adoption of anti-pollution devices for older uncontrolled motor vehicles.

The section operates two mobile test laboratories to carry out spot checks on 1969 and newer model cars. These checks indicate whether their pollution control devices are functioning efficiently or have been tampered with or removed. Maximum fine for tampering or removal is $100.00.

The Phytotoxicology Section is responsible for determining the degree and extent of air pollution injury to all types of vegetation throughout Ontario. It investigates complaints of economic loss to determine whether injury to plant growth is caused by air pollutants or by other harmful agents such as disease, insects, adverse weather, poor nutrition or mismanagement.

After making an assessment, the section prepares a report which goes to both the complainant and the owner or operator of the air pollution source allegedly responsible for the injury. If the parties concerned cannot reach an agreement privately, they may call on a Board of Negotiation to intervene. If no satisfactory settlement can be reached, court action may follow.

The section maintains a close surveillance of vegetation in areas of concern throughout Ontario. Ecological studies keep it informed of increasing or decreasing vegetation effects in the vicinity of existing pollution sources. Baseline studies are conducted in agricultural or forested areas before new major pollution sources become operational to determine pre-pollution endemic conditions.

The section also maintains specially-designed controlled environment facilities (growth chambers and greenhouse) to study the effects of air pollutants on vegetation. Experiments are conducted to supplement field investigations, to screen resistant plant species, and to determine air quality criteria for the protection of agriculture and forestry.

The Laboratory Section provides a chemical analytical service to the Air Management Branch. It conducts analysis of air-borne contaminants, vegetation and soil samples, and certain other materials (metal plates, pieces of rubber and nylon) that have been left exposed to the atmosphere for varying lengths of time. Each is analyzed for the effects of corrosive elements.

The need for analysis and measurement has accompanied the development of extensive sampling networks throughout the province and the increased investigation of source emissions and complaints directed to the Branch.

Research is conducted into ways of improving sampling and analysis techniques in order to expand the knowledge spectrum of air pollutants. This research is especially directed at certain harmful contaminants that are difficult or impossible to analyze by conventional monitoring methods.

Inter-Departmental Co-Operation

The work of air pollution control often involves the participation of other provincial government departments and agencies. Common programs and investigations are co-ordinated by the Pollution Control Advisory Committee. The Committee is chaired by the Deputy Minister of Energy and Resources Management. Six departments are represented -- Mines and Northern Affairs, Lands and Forest, Agriculture and Food, Health, Municipal Affairs, Energy and Resources Management -- as well as the Ontario Water Resources Commission.

The Department of Health provides advisory services through a physician on loan to the Air Management Branch. He advises on ambient air quality criteria and investigates specific complaints of health effects. In addition, the Department of Health conducts epidemiological studies.

International Co-Operation

Ontario directly shares an international boundary with three American states. Because of the problems of transboundary air pollution, the provincial government is involved in various programs at both federal and province-state levels, much of it through the International Joint Commission. Established by the Canadian and American governments, the Commission does not have any regulatory powers but does conduct comprehensive investigations and recommend corrective actions.

Various state and provincial personnel become involved in the Commission's work. A recent example is a study completed in January, 1971, on air pollution problems in the Sarnia-Port Huron and Windsor-Detroit areas of Ontario and Michigan.

Air Pollution Index and Alert System

A significant aspect of Ontario's air management program is its Air Pollution Index and Alert System. The Index was established to give warning of, and to prevent the adverse effects of air pollution build-ups during prolonged periods of stagnant weather. It went into operation in Toronto in March, 1970; Hamilton in June, 1970; Sudbury in January, 1971; Windsor in March, 1971. The Index network is gradually being expanded to other major centres in the province.

The Index is based upon continuous measurements of sulphur dioxide and suspended particulate matter, Ontario's two major air

pollutants. Both have been found in high concentrations during severe air pollution episodes in other parts of the world and extensive data is available relating severity of health effects to degree of pollution as measured by their presence.

The structure of the index is a numerical scale beginning at 0. Readings below 32 are considered acceptable, indicating concentrations of sulphur dioxide and suspended particulate matter that should have little or no effect on human health. At 58, people with chronic respiratory disease may be affected. At 100, prolonged conditions could have mild effects on healthy people and serious effects on those with severe cardiac or respiratory disease.

The alert system functions at four index levels -- 32 (Advisory Level), 50 (First Alert), 75 (Second Alert), 100 (Air Pollution Episode Threshold Level).

At 32, if meteorological conditions are expected to remain unfavorable for at least six more hours, owners of major sources of air pollution sources may be advised to prepare for possible curtailment of their operations. At 50 and 75, under continuing, adverse meteorological conditions, they can be ordered to curtail them.

At 100, the Minister of Energy and Resources Management can order all sources of air pollution not essential to public health or safety to cease operations. A reading of 100, however, is unlikely to be reached becuase of previous provisions for curtailment at lower index levels.

The highest Toronto index reading, based upon available figures, would have occurred in Toronto between November 30 and December 4, 1962. The index would have reached a peak of 155 during the evening of December 1, and 125 during the early morning hours of December 4. The average reading over this four day period would have been 95.

The most significant aspect of this particular pollution build-up was a dense smog which caused that year's Grey Cup game to be played on two separate days. There was no recorded incresase, however, in hospital admissions of people with respiratory ailments during this period, an indication of the margin of safety built into the index.

Financial Assistance For Air Pollution Control Programs

There are several ways in which companies, institutions and municipalities can obtain financial assistance for the installation of air pollution control equipment.

They can apply for grants up to the amount of the provincial sales tax paid on the equipment, obtain Ontario Development Corporation loans, receive certain federal sales tax exemptions and take advantage of accelerated capital cost allowances.

Grants are also available through the Department of Energy and Resources Management to universities and other organizations for research and training of persons in the field of air pollution, and to

municipalities to assist in the administration and enforcement of air pollution by-laws. The 1970 research budget was $318,000.

Suggested Code for Livestock Buildings and Animal Wastes

"A Suggested Code of Practice for the Establishment of New Livestock Buildings, Renovation or Expansion of Existing Buildings, and Disposal of Animal Wastes" was prepared in 1970 by the Departments of Energy and Resources Management, Agriculture and Food.

The Code is only a recommended guideline, but one that Ontario farmers are being urged to follow. Because of a population increase in farming areas and more intensive livestock and poultry production, greater animal wastes are being produced, often without adequate provision for disposal. As a result, serious odor problems have developed, affecting both rural and urban people.

The Code provides fair and satisfactory measures for dealing with the problem. Key measures stress the need for enough land on which to dispose of wastes, sufficient waste storage capacity (e.g. underground tanks), and adequate distances between livestock and poultry buildings and neighbouring dwellings.

Farmers following the Code can invite inspection of their premises. If they are considered to be operating within its provisions they receive a letter of approbation to that effect.

In Conclusion

Air pollution remains a serious problem in certain parts of Ontario. A considerable amount of progress has been and is being made, however, and major improvements are forthcoming. Within the next few years, virtually all sources of air pollution in the province will be under control, emitting either no contaminants at all or contaminants at acceptable levels of concentration. When this degree of control has been achieved, pollution build-ups will occur only during prolonged periods of stagnant weather.

In the meantime, everyone can do something about air pollution by:

1. burning wasteless fuels.
2. keeping cars well tuned.
3. turning off car engines when forced to wait for more than a minute or two.
4. walking or using public transportation rather than a car.
5. using hand lawn mowers.
6. not burning rubbish and leaves in open fires.

Open fires are a particular problem. A large percentage of the Branch's inspection time is taken up with their control -- time that could be put to much better use regulating more serious problems. In this area alone, therefore, there are significant opportunities for individuals to contribute to the control of air pollution. Much could be accomplished if everyone took advantage of them.

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Hon. George A. Kerr, Q.C., Minister J.C. Thatcher, Deputy Minister

PESTICIDES AND THE ENVIRONMENT

Introduction

Pollution of the environment by pesticides is a serious problem. It can only be overcome through proper use of these potentially dangerous chemicals by homeowners, farmers and exterminators. Good user practices combined Ontario's pesticides laws and careful evaluation of new chemicals and methods of use can turn what could otherwise be a bleak and ugly environmental future into one that's green and alive.

There is no immediate threat to human life from present pesticide contamination of man's food and water. However, cases of illness and even death have been reported as a result of misuse, improper storage, handling and transportation of these chemicals. Wildlife and aquatic life are more sensitive to the effect of pesticides which, even in relatively small quantities, can interfere with their reproductive processes or sometimes cause death.

Some scientists claim that pesticides can be a threat to plankton, the biological basis of the photosynthesis process which is the source of about 70 $^{o}/o$ of the world's oxygen.

At this point you may seriously question the value of pesticides, considering the damage they can do if misused. However, without pesticides man's food supply would be greatly decreased in both quantity and quality. Also, the threat to public health from the uncontrolled spread of vector-borne diseases would be as serious, or even more so, as the problem of pesticide contamination of the environment.

Consider the losses to insects in agriculture, even when pesticides are used. In North America today there are thousands of major species of insects that infest plants and crops, causing an annual loss of some $5 billion. In Canada alone, the losses suffered in the livestock industries from insect damage are estimated to be about $100 million a year. In 1946, the dawn of the era of new organic pesticides, the entire tomato crop of Eastern Canada was threatened by blight (a fungus disease). In 1962, in another case, the European corn borer insect caused a loss of 88 million bushels of corn.

Now, consider the losses that would be suffered if there were no pesticides. According to one expert, Ontario would lose 40 - 80 °/o of its apple production within two to three years as a result of the damage caused by just one insect species -- the coddling moth. Without herbicides, farmers would lose up to half of their entire crop production to the rapid spreading and choking action of weeds.

The fact that we have not had a major outbreak of vector (organism) - borne disease in Canada for some time is not just the result of the development of cures for these afflictions. Much of the

credit goes to pesticides for eliminating the problem at its source -- the carriers. There is no doubt that the Black Death (bubonic plague) could have been kept under control if rodenticides had been available in Europe and Asia in the fourteenth century.

Obviously it is not just a matter of banning all pesticides to save the environment, as one does not necessarily lead to the other. Rather, we need to make the most efficient and safe use of pesticides to prevent their adverse effects on our environment.

What's a Pesticide?

Just what do we mean by the term "pesticide"? The definition given in the Ontario Pesticides Act and Regulations is "any substance used for the destruction or control of insects, vermin, birds, rodents or other pests and fungi or vegetation including micro-biological agents".

The term "pesticide" denotes a general category of chemicals which covers the more specific categories of insecticides (chemicals that kill insects), herbicides (kill weeds), fungicides (kill fungus), rodenticides (kill rats and mice), miticides (kill mites), nematocides (kill nematodes), and so on.

In terms of chemical structure, they are divided into main groups: inorganics and organics. The inorganics are the older pesticides, such as the arsenicals and plant-derived materials (pyrethrum and derris dust). The modern organics of the post-1940s pesticide era are of more complicated chemical structure and include the chlorinated

hydrocarbon insecticides, the organic phosphorus insecticides, the carbamates and similar types.

In the home, pesticides occur most commonly as aerosol sprays and moth balls (paradichlorobenzene), and as liquids in larger quantities for garden and extermination use. On the farm, pesticides are purchased in bulk for large-scale application by ground equipment and aircraft.

There are more than 300 organic pesticide chemicals in general use in Canada today, marketed in more than 15,000 formulations. The Canadian agricultural chemical industry sells about $50 million of pesticides a year.

Misuse of these chemicals produces excessive amounts of pesticide residues in our environment. The improper use of a pesticide would be using one that is more toxic than necessary, or using more of a pesticide than is necessary, which could lead to contamination of humans, animals, their food and feed, and of air, soil and water. If we are to save our environment, we must always use the correct chemical and method of application. Directions on container labels must always be followed.

Pesticide Residues in Humans

Pesticide contamination of humans is mainly the result of eating foods containing pesticide residues (ingestion), spilling chemicals on skin (skin contact), and breathing fumes when using the material (inhalation). This poses no immediate threat to human life or health. In

fact, over the past 25 years, deaths from pesticide poisoning in the United States have averaged one a year for every million of population. (These deaths were caused by high occupational exposure, accidental ingestion and suicide attempts, not by general contamination).

What causes health officials some concern is the long-term or chronic effect on man of pesticides in our environment. This has yet to be determined. In North America, the level of DDT (dichloro-diphenyl-trichloroethane) -- a member of the chlorinated hydrocarbon group -- stored in human fat has reached a peak level of about 12 parts per million. We seem to be able to eliminate from our bodies any further DDT residues ingested. (One part per million, or ppm, is the equivalent of one pound of pesticide in one million gallons of water).

DDT is stored in fat because it is a fat soluble and, as an organic chemical, it has a great affinity for other organic compounds. The same principle applies to fat in milk.

Tolerance levels of pesticides in our food do not necessarily indicate the point at which harm can be done to the consumer. They are the maximum levels at which no effects can be seen in test animals, usually white rats, receiving this dosage. Just to be on the safe side, these levels are often adjusted to provide for a safety factor of a hundred or more.

In the United States, for example, the Food and Drug Administration annually conducts testing of 25,000 samples of various food commodities for residues of pesticides. From 1963 to 1967, the tests uncovered residues exceeding tolerance levels or administrative guide-

lines in only three percent of the cases. It was found that the majority of samples contained very low levels of these insecticides -- 75% of individual residues were below 0.11 ppm.

It is because the more persistent pesticide residues have the ability to travel great distances in air, water and transported food that human contamination by pesticides has reached people living in the remote, primitive subarctic regions of Alaska. A study of these people revealed a mean concentration of 1.4 ppm DDT and 3.8 ppm DDE (a derivative of DDT) in their body fat. Since neither of these chemicals was found in native foods and there is no record of DDT ever being used in that part of the world, it was assumed that the source was foods imported to the area. Drift of pesticide residues was blamed for the small quantities of DDT found in fat samples from polar bears living near the North Pole.

Human deaths from pesticides in North America, as previously mentioned, are rare and usually occur when these chemicals are carelessly handled. Cases of mass deaths from such poisoning are virtually limited to less developed countries. There, the lower level of education produces a lack of understanding of proper handling of these materials.

This is exemplified by a report of 75 deaths and about 500 illnesses from parathion contamination of bread in a town in Columbia, South America, in November 1967. Bottles of the insecticide - in what can only be termed a flagrant example of negligence - were shipped in the same truck as the flour from which the bread was to be made. One

of the bottles broke and the liquid spilled over the flour.

A similar incident happened in Turkey. Seed grain treated with the insecticide benzene hexachloride (BHC) was eaten instead of planted; there were 330 deaths and 3,000 illnesses.

Causes of Pesticide Contamination

General contamination of the environment can be the result of intentional or unintentional (direct or indirect) application of pesticides. It is intentionally applied to animals, crops, soil and water -- in the latter case for the control of mosquitoes, water weeds and trash fish. Other examples of direct application are household and garden use and the mothproofing of clothing and household fabrics.

Virtually all living organisms are affected by indirect contamination. This is caused by pesticide drift in the atmosphere followed by rain-out or snow-out, mishandled pesticide operations, improper dumping and cleaning of spray tanks, dumping of chemicals into the sewage system, industrial wastes of pesticide manufacturers and mothproofing industries using pesticides, dumping of food products containing residues exceeding tolerance levels, animal dipping vats, and decaying plant and animal tissue.

Once in the environment, these chemicals are broken down into simpler and possibly safer substances, according to individual characteristics and surrounding conditions. Generally speaking, the organic pesticides either vaporize (escape as mist), oxidize (combine with oxygen in air or from other compounds), hydrolize (form an acidic or

basic solution), or metabolize (break down into simpler substances when attacked by organisms). Since there is a wide variation in decomposition rates (for example, chlorinated hydrocarbon insecticides as a rule are more persistent than organic phosphorus ones), the hazard to man varies. Some pesticides can be tolerated in relatively large amounts, while others cannot. Some persist for years, others last for a few weeks or months.

As the newer organic pesticides are subject to decomposition by physical and biological means, they are generally less persistent than some inorganic pesticides, mainly the arsenicals.

Pesticide Residues in Soil and Vegetation

The persistence of pesticides in soil is determined by a number of factors. Insecticides and herbicides persist longer in soil high in organic matter, because they are attracted to and are not readily released from this matter. Moisture in the soil greatly increases the evaporation and breakdown of certain pesticides. Some micro-organisms in the soil can break down pesticides into other chemicals.

The type and the amount of material applied, formulation, dosage and number of applications per season will have a determining effect on the level of contamination and the pesticides residue in the environment.

Weather factors, such as increased temperatures, light, humidity, air movement and rain, can speed up the breakdown of the organic pesticides and thus reduce their persistence.

Plants to which pesticides are directly or indirectly applied play a part in residue concentration and persistence. Cover crops, such as alfalfa, reduce the effect of wind that stirs up pesticide- contaminated soil particles. Persistence is also determined by a plant's shape, density of foliage, protection of edible portions by leaves, enzyme systems, and surface fuzz or waxiness. Generally, pesticides stored in plants are diluted as the plants grow.

During and after harvest, pesticides remaining on plants can be further reduced by trimming and stripping operations on edible commodities, and washing and cooking in the home will remove a great percentage of the residue.

There has been only one case in Canada where soil contamination was of a dangerously significant level, according to the Federal Food and Drug Directorate. This occurred in the valley of Grand Forks in British Columbia about four years ago.

In fact, there are some claims that pesticides have been applied to only five percent of the world's arable lands.

Pesticide Residues in Water and Aquatic Life

Water and aquatic life are particularly susceptible to pesticide contamination. Surface and ground waters are affected by direct or indirect ground and aerial spraying, runoff from treated areas, leaching, waste discharge from pesticide manufacturers, and chemical misuse.

Contamination of water can be either of a chronic or acute nature. Chronic contamination usually occurs at levels of one part per billion or lower following gradual runoff and waste discharge. Acute contamination is of a higher, short-term nature and results from direct application to water, runoff from land following heavy rains, or accidents during pesticide application.

The dangers of biological magnification - the build-up of pesticide residues in the succeedingly higher levels of a food chain - is at its greatest in water. For example, DDT was applied in 1949, 1954 and 1957 to control gnats in the waters of Clear Lake, California. The dosage rate was 14 parts per billion. Later, it was found that plankton built up a residue level of 5 ppm. By eating the plankton, the fish concentrated the pesticide in their fat at levels of from 40 to 2,500 ppm. This was sufficient to kill western grebes (a species of waterfowl) feeding on the fish.

There are other ways for pesticides to build up in aquatic life. Large amounts of water are strained through the gills of fish. This filters out particles containing pesticides. In one experiment (Premdas and Anderson) Atlantic salmon, exposed to water containing 1 ppm of DDT for five minutes, concentrated the insecticide at a level of 1.56 ppm in their spleens and livers. Those left in the water for an hour reached levels of 31 ppm.

Oysters are just as efficient in removing such chemicals from water. One case was reported where a seven-day exposure to water containing 0.01 ppm of DDT resulted in stored levels reaching as high

as 151 ppm.

Pesticide contamination of water caused by misuse is taking its toll in the fishing industry. Over the past four years the U.S. government has withdrawn from the market hundreds of thousands of cohoe salmon caught in Lake Michigan -- the most heavily contaminated of the Great Lakes. The fish contained more than the maximum 5 ppm of DDT allowed for fish under U.S. standards.

Trout in Ontario lakes have also built up high levels of DDT. Five Lake Simcoe trout examined in 1967 carried DDT levels of from 12.55 to 18.44 ppm. In Lake Muskoka, DDT levels in trout averaged 29.7 ppm (and in whitefish 13.7 ppm). According to the Ontario Lands and Forests Department, levels of 3 ppm of DDT can disturb lake trout reproduction. This department has for some time been carrying out re-stocking programs to maintain the population of lake trout.

Thousands of trout were killed in a four-mile section of the Sable River in Prince Edward Island when dithane M-45 was carelessly used. Investigation showed that a potato sprayer machine loading water from the river had spilled back some water containing the dithane M-45. Had the machine been equipped with a proper device to prevent backflow, this would have been prevented. Also, empty chemical bags were found in the water. Officials say it may take several years before the river regains its full, normal trout production.

The insecticide, Endosulfan -- which has been used without major incident in Canada for the past 12 years -- was recently

accidentally used in Germany to such an extent that hundreds of thousands of Rhine River fish were killed.

Pesticide Residues in Birds

Waterfowl, such as the western grebe previously mentioned, suffer the effects of high levels of pesticide contamination by feeding on already contaminated fish. A study reported by the U.S. Department of Health showed that 71% of waterfowl and their eggs from selected areas of Canada and the United States, tested from 1961 to 1963, contained residues of chlorinated hydrocarbon insecticides.

Upland game and other birds acquire pesticides by other means. For example, biological tests of pheasants and Hungarian partridges in Alberta's upland game areas found them to be contaminated with mercury from treated seeds they consumed from farm areas. They also contained insecticide residues.

One classic case of pesticide misuse resulting in the build-up of lethal concentrations of residues occurred at the University of Michigan in the mid-1950s. DDT was sprayed on campus trees to kill bark beetles that were spreading Dutch elm disease. The beetles began to die off, but so did a great many robins. Looking into the tragedy, researchers found that the robins had eaten earthworms which, in turn, had fed on DDT-covered leaves that fell to the ground. By eating these worms, the robins accumulated lethal concentrations of DDT in their systems.

Pesticides stored by birds in fat may have a delayed but just as deadly effect. During periods of stress or reduced feeding --

as in migration -- this fat is used to sustain life. As the fat is metabolized and circulated through the digestive system, so also is any deadly level of stored pesticides that otherwise would have had a lesser effect.

Some species of Canadian birds are in danger of becoming extinct because of the effects of pesticides -- and also as a result of the destruction of their habitat by man. According to the Federal Department of Northern Affairs and Rural Development, seven species of birds have seriously declined in number over the past 20 years. These are the greater prairie chicken, peregrine falcon, prairie falcon, pigeon hawk, Swainson's hawk, bald eagle and gyrfalcon.

Another effect of DDT which contributes toward the decline of bird populations is the fact that this insecticide upsets their calcium production. As a result birds may lay eggs too thin-shelled to be hatched.

Pesticide Residues in the Atmosphere

Pesticides in air are an original pollution burden, unlike more recognized forms of air contamination that add to chemicals already in the air. Pesticides enter the air through the escape of fine droplets of chemicals during ground or aerial spraying; evaporation of residues, stock materials or wastes; the stirring of pesticide-containing soil particles by wind; smoke from the manufacturing process; burning supposedly empty containers; warehouse fires.

In some cases -- mainly chlorinated hydrocarbon chemicals --

conditions may be such that as much as half of the applied material is unaccounted for after an area has been treated. Much of the missing amount is carried as fine particles or droplets to distant areas.

The distance pesticide residues drift in air depends on the speed and direction of the wind, the topography over which the pesticide is carried, and weather phenomena such as inversion layers that have a containing effect on the floating chemicals.

Great distances can be covered if the required conditions come into play. Pesticides in air can travel from one country to another and even one continent to the next. They can also reach great heights. The source of 0.3 parts per billion of DDT found in ice laid down on Washington state's Mt. Olympus in 1964 is suspected to be rain-out or snow-out of DDT in air.

The persistence of pesticides in air is related to both weather conditions and the nature of the chemicals. Rain or snow serves to clean the air of all particulate matter, including pesticides. Oxidation in air is more rapid, since more of the chemical's surface is exposed. Also, if spray equipment is properly adjusted and the formulation correctly mixed, spray droplets will be large enough to fall mainly within the area being treated.

Pest Control Research

Even though the advantages of properly used pesticides clearly outweigh any disadvantages, the people involved in this field are continuously striving for improvements. Research scientists, government

agencies and pesticides manufacturers are presently searching for even safer chemicals and non-chemical methods of pest control.

There are some promising although not yet fully practical non-chemical methods. The sterile male technique involves the release of huge amounts of male insects incapable of propagating the species. Eggs laid by female insects which mate with these males are unfertilized and do not produce offspring. In this way, the species is largely reduced or effectively eliminated.

Predatory insects -- those that feed on crop-destroying insects and not the crops -- have been used successfully in some instances. Although the first use of this method was in 1880 when Australian insects were imported to prey on insects threatening California citrus trees, it has not yet proved to be an effective control in all situations.

Viruses deadly to insects but harmless to man are now being developed and will soon be in general use. One such virus was successfully field tested against tobacco cutworm in 1969 by the Belleville (Ontario) Research Institute, in co-operation with the Canada Agricultural Research Station at Delhi, Ontario.

Botanists are also contributing to this research drive. Their efforts are directed toward finding new plant species resistant to insects and other pests. They are even trying to find a plant species that would give off chemicals to check the growth of weeds.

National governments seek to prevent new insect species

from entering their respective countries and establishing themselves in new environments. The public can help in this regard by observing border quarantines barring the entry of plants, animals and other pest carriers. In an extension of this method, some governments help other countries to eliminate their pests. This is both an act of generosity and a means of preventing these species from crossing borders into other countries.

Massive but carefully controlled campaigns against various species of pests have been mounted to effectively eradicate the problem in a specific area. Such campaigns may combine the use of present-day chemicals with some of the more promising new techniques.

Insects, in some ways, determine the direction taken by research in the development of new chemicals. They are able to develop resistance to many chemicals within a few generations, thus forcing the development of new insecticides. Since 1951 more than 70 species of insects have developed resistance of some kind to many organic insecticides.

Government Supervision of Pesticides

Whenever monitoring programs and scientific research indicate that certain pesticides or their methods of use are posing a significant problem in our environment, the government of Ontario introduces the necessary restrictions or bans. A case in point are the chlorinated hydrocarbon insecticides, DDT, aldrin, dieldrin and heptachlor, the use of which has been banned in the Province since January 1, 1970.

Recommendations in this field are made to the provincial government by the Pesticides Advisory Board, a group of experts from the agricultural, chemical, pest control and extermination industries. Adopted rulings -- which become amendments to the Pesticides Act and Regulations -- are enforced by the Pesticides Control Branch of the Department of the Environment. The Service advises homeowners and licensed applicators on the proper use of chemical pesticides. It ensures public safety by licensing and supervising commercial applicators.

Safe Pesticide Use

Homeowners, farmers and exterminators can all contribute to a reduction in the amount and toxicity of pesticide residues in the environment by following the proper rules.

The least toxic material that will do the job should be used - and in the smallest amount that can be effective. The proper chemicals should be chosen and, if sufficient quantities are being used, synergists or additive chemicals can be used to increase effectiveness without increasing the dosage. Pesticide chemicals themselves should not be mixed together.

The following precautions should be taken:

1. Read the pesticide container label every time the chemical is used
2. Do not use household containers as measuring devices, or spray near them or near food
3. Do not smoke or eat when applying pesticides
4. Keep spray away from pets and their dishes

5. Keep flammable chemicals away from heat or flames

6. Wear protective clothing if using large or toxic amounts of pesticides

7. Spray in the same direction the wind is blowing during out-of-doors operations

8. Store pesticides in their tightly closed original containers under lock and key and away from food, medicines, utensils and curious children

9. Do not save empty containers, but dispose of them in a way they will not contaminate the environment

10. Wash clothing and skin thoroughly if chemicals are spilled on the body

11. Take a shower or bath and change clothing after using relatively large amounts of pesticides.

We can all safely enjoy the benefits that the proper use of pesticides offer us. By following government pesticide laws and recommendations, we will maintain a bountiful agricultural production and a high public health standard, while at the same time keeping our environment clean and alive. If we are careless, or abuse the good inherent in pesticides, we will condemn ourselves to a continuously declining quality of life.

This publication was prepared by J.G. Kurys, Education Officer, Pesticides Control Service, Ontario/Department of the Environment.

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Ontario's Conservation Authorities and The Conservation Authorities Branch of the Provincial Government

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Environment Conservation in Ontario

Department of Energy and Resources Management

Hon. George A. Kerr, Q.C., Minister

J.C. Thatcher, Deputy Minister

ONTARIO'S CONSERVATION AUTHORITIES

by

A.S.L. Barnes, Director Conservation Authorities Branch

Dr. Luna Leopold, Chief of the United States Geological Survey, has described The Conservation Authorities Act "as one of the most advanced approaches to conservation anywhere", and Donald Williams, Chief of the Soil Conservation Service of the United States has said it is "an outstanding example of community action for conservation". It is unique in Canada, in North America and, until quite recently, apparently unique anywhere in the world. It has been studied by both professionals and parliamentarians from other provinces, the United States, the United Kingdom and from countries in nearly every continent.

Prior to 1940, the possibility of a water shortage in Ontario, with 17 per cent of its area covered with water and Southern Ontario almost surrounded by the Great Lakes, was undreamed of. True there had been floods in the past and low stream flows in summer. Records indicate that there has been little if any change in the total amount of precipitation over the last hundred years, but there has been a marked increase in the frequency and intensity of floods and a consequent reduction in summer flow in streams. This has been aggravated by the increasing demand for water for industrial, domestic and agricultural use.

<u>The Conservation Authorities Act, 1968</u> (1)

Because of the concern about water supplies as well as other renewable natural resources The Conservation Authorities Act was passed by the Government of Ontario in 1946.

When it was passed the legislators had three premises in mind:

1. The initiative must come from the local people

2. The best unit on which to co-ordinate all conservation work dealing with renewable natural resources is the watershed (2)

3. If the local people show the initiative, the Government stands ready to provide technical advice and financial assistance in the form of grants.

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(1) The Conservation Authorities Act, 1968, Statutes of Ontario, 1968, Chapter 15.

(2) Watershed in this paper means the whole drainage area of a river basin.

Local interest may be shown first by a municipal council, a service club or any other group of conservation-minded citizens. They are then advised to call an informal meetings, inviting representatives from all municipalities in the watershed and all interested citizens to attend. At this meeting a representative of the Ontario Government is present who explains how an Authority is established, what its functions are and endeavours to answer all questions.

Following this unofficial meeting, if two or more municipalities (cities, towns, villages and townships) petition the Minister (Energy and Resources Management), he must call an official meeting to discuss the establishment of an Authority on the watershed or group of watersheds concerned. The Minister then sets the date, time and place of meeting and notifies all the municipalities lying wholly or partly in the watershed or watersheds.

The council of each municipality may appoint representatives to attend the meeting on a population basis, but the maximum number from any one municipality is five. A quorum for the meeting is two-thirds of the total number of representatives entitled to attend. At this meeting the whole question of establishing an Authority is exhaustively explored and methods of financing are carefully outlined. At the end of the meeting one of the municipalities which asked for the meeting usually presents a resolution requesting the establishment of an Authority. If this resolution is passed by not less than two-thirds of the representatives present it is forwarded to the Minister, and the Authority is established by the Lieutenant Governor-in-Council who also designates the participating municipalities (including those which may have voted against the resolution) and the area over which the Authority has jurisdiction.

Conservation Authorities

Following the passing of the Order-in-Council the Minister calls the first meeting of the Authority, to which each municipality appoints its representative or representatives. Again the number is based on population. At this meeting the Authority elects a chairman and vice-chairman from among its own members. If an Authority receives a grant from the Government, the Government may appoint three representatives and in some cases the chairman of the Authority.

The Authority then is a body corporate and may undertake almost any project in the field of conservation of renewable natural resources. The Authority may elect or appoint an executive committee from among themselves and delegate all or any of its powers, except the power to raise money or enter into contracts, to the executive committee. It may also appoint a number of advisory boards such as finance, water control, forestry, land use, wildlife, and recreation. These boards have been proved to be most valuable not only in accelerating the work of the Authorities but also in maintaining the interest of representatives, though members of advisory boards are not necessarily municipal respresentatives and frequently include engineers, foresters, agrologists and biologists.

When a local Authority is established, the Conservation Authorities Branch of the Ontario Department of Energy and Resources Management makes a complete conservation survey of the watershed under the Authority's jurisdiction at no cost to the Authority. This survey covers the subjects of water, land, forests, wildlife and recreation.

Subsequently a report with recommendations is prepared for the guidance of the Authority. Though the report contains numerous recommendations and may serve as a plan for the Authority to follow over a long period of years, it is the Authority itself which makes the decisions as to which projects shall be undertaken and when they will be carried out. The Conservation Authorities Branch also seconds a resources manager, who is a provincial civil servant, to each Authority to direct its operations under instructions from the chairman of the Authority.

The primary work of the Authorities is water control. This involves the construction of dams and reservoirs to prevent floods and store water during periods of high flow in the spring and release it gradually during the summer to augment low natural flows to provide water for domestic, industrial and agricultural use as well as the dilution of sewage effluents. Where feasible the reservoirs are also used to a limited extent for recreation purposes. In addition channel improvement works are undertaken to pass flood waters safely through urban areas.

Though water is the most important of the natural resources which fall under the jurisdiction of the Conservation Authorities, the Authorities also co-ordinate the works undertaken in the other fields of resource management such as forestry, land use, wildlife and recreation. For example, some 130,000 acres of land, submarginal for agriculture, have been acquired and reforested, gully control work and the establishment of grassed waterways has been undertaken and areas, particularly wetlands, have been set aside for wildlife management. In most cases the forest and wildlife lands have been placed under agreement with the Department of Lands and Forests for management. Through the co-operation of the Department of Agriculture Authorities have encouraged farmers to reduce run-off and loss of top soil from their lands by modern methods of farming.

All Authority owned lands are used for some form of recreation - hiking, nature trails and perhaps hunting. Only 3½% of their lands are used for intensive or developed recreation such as picnicking, camping, boating and swimming, and about one-tenth of Authority budgets is devoted to recreational developments. However, with the increasing amount of leisure time and improved transportation facilities, the demand for recreation areas is constantly expanding. Where rivers flow through urban centres it has been the policy of many Authorities to acquire all flood plain lands along the rivers, do the necessary channel improvement work and then lease the flood plain to the municipality for a period of 99 years. The Authority

retains ownership of the land and controls all building, but the municipality develops and maintains the flood plains as parkland. Under this system Metropolitan Toronto, for example, will have 7,200 acres of parklands on the flood plain lands of four major streams which flow through the city. Similar projects are being worked out in numerous urban centres throughout southern Ontario.

Grants

In addition to making conservation surveys and providing technical assistance to Authorities, Ontario has developed a system by which an Authority can obtain very substantial grants for almost any conservation work which it wishes to undertake. These grants are not statutory grants but are policy grants and in general are 50 per cent of the cost. However, there are several exceptions under which an Authority may obtain a 75 per cent grant.

Practically all administration costs including salaries and travelling expenses of members and employees, office rent and equipment, expenses connected with publicity, public relations and education are eligible for 50 per cent grants. Nearly all capital expenditures such as channel improvement work, tree planting, gully control and the development of wildlife and recreation areas are also eligible for 50 per cent grants. However, 75 per cent grants are availably for preliminary engineering up to the point of calling for tenders for the construction of small reservoirs, and for the maintenance of all water control structures.

In certain cases where the Authority has prepared an overall water control plan for a whole watershed it may receive a grant from the Government of Canada under The Canada Water Conservation Assistance Act. (3) Under this Act Canada may provide 37.5 per cent and the remaining 25 per cent is raised by the Authority by levy on its member municipalities.

In fact the Authority raises all its share of the cost by levy on its member municipalities and the levy is usually based on assessment, though for capital projects it may be based on assessment or a combination of population and assessment. Costs of such items as administration, forestry, wildlife and recreation are spread over all member municipalities. However, costs of major water control projects are based on benefit assigned to each municipality as decided by the Authority. If a municipality is dissatisfied with its levy it may appeal to the Ontario Municipal Board.

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(3) Canada Water Conservation Assistance Act - Statutes of Canada 1952-3, Chapter 21.

Conclusion

The great strength of the Conservation Authorities movement lies in local participation. Local people are closer to the problems. They raise a fair share of the funds required and take an intimate and even personal pride in the development of projects in their own watershed. At present there are 38 Conservation Authorities in Ontario with jurisdiction over 30,000 square miles. The Authorities embrace 905 representatives from 561 municipalities in Ontario. These representatives are, on the whole, dedicated to the cause of conservation. They devote a great deal of their own time to conservation work for which most of them receive only a per diem allowance and mileage for meetings attended.

This is probably one of the most outstanding examples to be found anywhere of democracy working through three levels of government to achieve the wise use of the renewable natural resources in an area which is experiencing an unprecedented growth of population, urbanization and industrialization.

THE CONSERVATION AUTHORITIES BRANCH OF THE PROVINCIAL GOVERNMENT

While individual Conservation Authorities operate autonomously within the confines of their watershed(s) though with technical and financial assistance from the provincial government, the Conservation Authorities Branch of the Ontario Department of Energy and Resources Management is responsible for the administration of the Conservation Authorities Act and of the Parks Assistance Act throughout the province. This Branch is made up of 7 sections:

1. Field Services
2. Engineering
3. Forestry and Land Use
4. Biology
5. Planning
6. Recreation
7. History

The functions of the Branch are to

1. make an overall environmental study and prepare a conservation report including a conservation plan for each Authority
2. examine proposed projects submitted by Authorities and make recommendations to the Minister for approval or otherwise
3. check all land purchases and inspect all projects to ensure that government grants are spent in accordance with approvals, and that projects meet standards and specifications approved
4. provide a resources manager for each Authority who administers the Authority's field program
5. provide technical assistance from head office to Authorities in all aspects of resources management.

Field Services Section

The first and major responsibility of the Field Services Section is the direction and supervision of the staff of 23 resources managers. These men are provincial employees assigned to locations across Ontario. Duties and responsibilities of the resources managers include

1. assisting and advising Authorities in the administration and the execution of their total resource management program. As a technically trained person the resources manager is expected to advise and assist the Authority in the full range of its work. He makes suggestions for projects and may be asked by the Authority to obtain information on methods and means of carrying out the projects. The resources manager will be required to assist the Authority in the preparation and submission of briefs to the Department and in the planning of Authority projects. He will be expected to work closely with the officers, executive and various boards of the Authority

2. acting as liaison officer between the Conservation Authority with which he is associated and the Department of Energy and Resources Management as well as with other departments of the provincial government concerned with conservation. The Conservation Authorities Branch of the Department of Energy and Resources Management has specialists in the various fields of resources management on its staff. Their advice and assistance is available to the Authority and to the resources manager on request. Similarly, technical advice is available from the Departments of Lands and Forests, Agriculture and Food, and the Ontario Water Resources Commission. The resources manager will also have contact, as required, with various private consultants in the resource management field

3. representing the province's interests in the Authority through the Department of Energy and Resources Management. Most Authority projects receive a provincial grant and the government must be assured that the grants which are given are being used wisely and for the purposes for which they were requested

4. maintaining contact with the field staff of such departments as Lands and Forests, Agriculture and Food, Tourism and Information, Municipal Affairs and similar resource-related departments with whom the work of the Conservation Authorities is closely linked.

Senior resources managers also serve on almost all of the Regional Advisory Boards to the Provincial Advisory Committee on Regional Development.

All resources managers undergo a period of on-the-job training upon first joining the staff. The length of the training period varies with the resources manager's aptitude in meeting the requirements of the job and is influenced by any previous pertinent experience he may have had. In general, training lasts for a period of one to two years after which he is assigned to work more or less independently with a Conservation Authority.

Much of the technical assistance given by the Branch to Conservation Authorities is channelled through the resources managers. The Field Services Section co-ordinates the advisory services to the field. This Section works with Personnel in selection of resources managers, organizes in-service training programs,

staff conferences and seminars, and other duties associated with field staff.

Head office personnel of this section attend meetings of Authorities to give advice in departmental policies and generally to represent the Director and Branch on occasion.

Engineering Section

The primary work of the Conservation Authorities in Ontario is resources management. As this often entails the construction of large structures such as dams and channel improvements, the Engineering Section has a major role in the work of the Conservation Authorities Branch. In addition to its duties and responsibilities to the Department, it provides valuable technical assistance to each of the 38 Conservation Authorities, most of which do not employ any technical staff.

The engineering work begins with a field survey of the water resources of the watershed. The data and information collected are then integrated with those from the other sections of the Branch to prepare a conservation plan which forms part of a comprehensive conservation report to the Authority. The survey includes an appraisal of the existing water resources and the collection of data on the physical characteristics of the area under study which affect the streamflow and runoff. Specific water problems such as flooding, low flow, pollution and fluctuating water levels are also investigated. These data are then analyzed and recommendations prepared for the Authority's guidance. The report indicates the remedial measures required to conserve the water resources, to alleviate existing water problems, and contains guidelines for the development of Authority policies and objectives.

The second phase of the engineering work results from the initiative of the Authorities to proceed with the construction of control works. Under the Conservation Authorities Act, all such work must be approved by the Minister of Energy and Resources Management. Therefore the request must be reviewed and a recommendation prepared. If approved, the project is reviewed and supervised from the preliminary engineering through final design and construction. In most cases this involves close liaison with consulting engineers engaged by the respective Authorities.

In view of the potential dangers involved, the Engineering Section supervises and controls the actual operation of all Authority-owned major water control structures. This involves a careful analysis of all the hydrometeorological factors affecting the streamflow, and the development of procedures for the safe and efficient operation of the structures. A close day-to-day watch on the streamflow and weather conditions throughout the province and knowledge of each river based on experience is also necessary to provide an effective river forecast and flood warning system.

The inspection of all water control structures, particularly of dams, to ensure that they are properly maintained is another responsibility of the Engineering Section. Each structure is inspected at least once a year and a report of the deficiencies is made to the Authority. A further inspection is made to ensure that the maintenance work is actually carried out.

In addition to the above the Section provides services to other governmental departments and agencies, maintains liaison with officials of the federal government on joint cost-shared programs, and carries out some research work in the fields of hydrology and the techniques of water management and control.

Forestry and Land Use Section

The Forestry and Land Use Section investigates rural lands in accordance with their capabilities for agricultural or forest production and makes recommendations regarding their proper use. Information already available from previous studies, such as county soil surveys, is examined and is then supplemented by field surveys carried out by crews of forestry and agriculture students supervised by professional staff members.

Woodlands are mapped and classified as to cover type and condition. Examples of care or abuse are noted. Logging practices which contribute to erosion and siltation of streams are described. Areas submarginal for agriculture are identified as potential reforestation sites.

Similarly agricultural soils are classified and the effects of present agricultural practices examined, particularly those practices which result in erosion or stream pollution. Trends towards intensification or changing agricultural use are examined.

From the findings of the above surveys and consultation with other sections where they are affected recommendations are developed to guide the Conservation Authorities in formulating programs for better use of land resources throughout their areas. These recommendations include

1. designation of lands for public acquisition primarily for forest production

2. designation of lands to be acquired for combined forest and wildlife or forest and recreation area

3. proposals for demonstrations and other educational programs to instruct private landowners in methods and encourage the adoption of such improved land use techniques as

    (a) reforestation

    (b) windbreak plantings for erosion control and shelter for crops and buildings

(c) soil protecting cultivation methods such as contour tillage and strip cropping

(d) installation of grass waterways and tile drainage

(e) livestock control to prevent stream bank erosion

4. suggestions for programs of technical and financial assistance to aid landowners in applying improved land management methods.

Biology Section

The work of the Biology Section includes the following functions:

1. To integrate plans with the Engineering Section with the aim to improve fish and wildlife population where possible, and to avoid harmful after-effects

2. To prepare a review of the fish and wildlife resources in each Authority, in co-operation with the district offices of the Department of Lands and Forests. This includes all of the mammals, birds, fish, amphibians and reptiles, and a record of any species which has been or should be introduced or is endangered. Management plans for wildlife in areas acquired by conservation authorities are also made

3. To describe the wildlife and fish habitats, including the sounding of any lakes which have not yet been sounded, to map the aquatic vegetation and spawning areas of any lake or river, particularly if they affect fish and wildlife, and to make recommendations for the improvement of the habitat.

4. To map the permanently flowing streams, using insect indicators, particularly the waters suitable for trout. (This is carried out by collecting the young stages of insects from the bottom of streams, placing them in vials containing a preservative, and identifying them with microscopes.)

5. To note any sources of serious pollution in co-operation with the Ontario Water Resources Commission, using its data where applicable and adding to them with field and laboratory tests, and to make recommendations for the eradication or control of the pollution

6. To make note of any refuse disposal system which causes or may cause pollution of streams or constitute a public nuisance, and to recommend control of such refuse disposal

7. To map areas having rare or unique flora or fauna and to recommend the acquisition of areas for the retention of such areas or species

8. To prepare a conservation report on all the above

9. To represent the Department on three committees of the provincial government:

   (a) The Industrial Wastes Sub-Committee of the Pollution Committee

   (b) the Refuse Disposal Committee, and

   (c) the Committee for the Management of Roadside Vegetation

10. To attend the annual Industrial Wastes Conference and the annual North-east Wildlife Conference, or the annual meeting of the American Fisheries Society

11. To advise resources managers of Conservation Authorities on technical problems.

Conservation Planning Section

The ever increasing rate of urban development in all portions of Ontario is creating many resource problems. The Conservation Planning Section is concerned primarily with minimizing these development impacts on the water and land resource base. The urban development problems are inter-related with many other resource and conservation problems. The inter-relationships demand viewing urban planning problems in light of the total environment.

Society today is becoming more leisure oriented which, coupled with increasing disposable income, is posing great demand for our limited resource base. Socio-economic trends indicate that increased demand will be made by individuals for open space, recreational land, and other environmental resources.

The Conservation Planning Section provides professional assistance to local Conservation Authorities upon request. This may take the form of reviewing municipal official plans, proposals for development, or discussion of regional plans. Close liaison is established between this Section and other planning groups within and outside the provincial government. Environmental comments are solicited by many agencies and persons ranging from detailed comments on site conditions for subdivisions to more general discussions about regional planning concepts.

Research is carried out by the Section. The conservation reports which are completed for each Conservation Authority now have a conservation plan. The input at this stage involves basic inventory techniques, demographic analysis, socio-economic analysis and locational analysis. The Conservation Planning Section collates

and extrapolates information and data from inventories completed by other Sections of the Branch to prepare a conservation plan.

The Section's concern for the physical environment extends to the regional scale. Regional concepts and plans of other provincial departments, municipalities, and private enterprise are revised in light of physical environmental limitations.

Social, economic and political factors are also considered in reviewing proposals by engineers and developers for works intended to ameliorate certain physical or resource problems as there is rarely only one right way. New techniques are utilized as they become available. One such new technique is the use of the 'ecoplan approach' which involves a combination of applied systematics of biology and information theory.

In conclusion the Conservation Planning Section is concerned with the interface between human and physical resources. The physical resource is viewed as a finite fragile system on and within which the ever-present human activity occurs. It is the goal of this Section to minimize environmental impacts created by human activities, especially in a manner that will protect and preserve our environmental quality for future generations.

Recreation Section

The Recreation Section of the Conservation Authorities Branch was established in 1966, in recognition of the growing recreational involvement of Conservation Authorities.

The degree to which Authorities are becoming more concerned with the varied recreational capabilities of their watersheds is apparent in the volume of development of conservation areas across the province. While these areas cater primarily to the day-user, development of camping facilities where they are warranted is becoming more widespread.

Currently, visitors to conservation areas number over three million a year, and therefore impose a major management responsibility upon the various Authorities. The acquisition of areas for the conservation of irreplaceable natural features such as unique floral and faunal, geological or topographical features, as well as outstanding natural esthetic features such as landscape vistas, is becoming more common. These amenities have a recreational and stimulative value that is as significant as the beach, campground, or picnic area.

The functions of the Recreation Section may be divided into three primary areas:

1. To carry out recreation field surveys of Conservation Authorities

2. To assist Authorities in planning, developing and maintaining on-going recreation oriented programs

3. To maintain liaison in the area of recreation planning with other agencies of government, as well as the academic, consultative, and private organization communities.

Field Surveys

The recreation portion of the conservation surveys conducted by the Branch is designed to assist the Authority in initiating a recreational land management program.

The well designed conservation area will, in general, be a multiple purpose tract of land. The aim is to ensure that the natural resources in any given area are utilized in such a way that unique values are conserved for the future. Those values which are recognized today will appreciate as urban sprawl envelops more of the natural landscape.

The recommendations are further designed to integrate with ongoing programs in other governmental agencies and should complement or assist in rectifying the existing recreational or environmental situation. The final report becomes a source of information and guideline to assist the Authority in recreation planning.

Assistance With On-going Programs

All Authorities are engaged in the on-going planning, development and maintenance of conservation areas under the terms of the Conservation Authorities Act, 1968. It is the responsibility of the Recreation Section to provide technical assistance to the Authorities in the area of public recreation. Services of a consulting nature on specific problems may be provided and review of projects eligible for provincial grant is required prior to approval. Assistance to Authorities seeking the services of private consultants may also be provided as the need arises. The expanding recreational role renders this form of professional consultation increasingly necessary.

Liaison With Other Agencies

Collectively the Conservation Authorities constitute the second largest managerial agency of public recreation land in Ontario. For this reason it is essential that close working relationships be maintained with other agencies of the province and federal government involved with recreational land planning. Exchanges of information take place with such inter-departmental bodies as the Canada Outdoor Recreation Demand Study, the Canada-Ontario Rideau and Trent-Severn Study, the Ontario Tourism and Outdoor Recreation Plan Study, the Niagara Escarpment Study, as well as the many individual departments and branches within the Ontario Government that are involved with various recreation planning matters.

The Recreation Section also administers the Parks Assistance Act under which provincial grants are extended to municipalities for the acquisition and development of certain facilities catering to demands for camping and trailers.

From time to time staff attend conferences, prepare written material and give lectures dealing with conservation and recreational problems.

History Section

The History Section provides a great deal of the background material for use in conservation reports and conservation plans which serve as guidelines for Conservation Authorities. It furnishes records of floods gleaned from many sources, including newspaper reports. It provides data on early lumbering operations and the clearing of land as well as figures on the movement of populations. It traces improvements in transportation and agriculture, and the development of industry. In short, it furnishes an economic and social history of a watershed, not a history of battles and the lives of famous men. The section head also advises Authorities on the restoration of historical buildings and the development of pioneer villages.

Specifically, the history section of the conservation report shows what type of forest cover existed, what crops have been grown, where and why some crops survived or failed, the types of domestic and wildlife that an area has supported, attempts at diverting or building water courses, the beginnings, and sometimes, failures of various kinds of industries, why people stayed or moved on, and so on. Although the report is resource oriented, and is written as far as possible as a continuous narrative, the names of local persons do enter when they have had a large part in the development of local resources.

The content of the report helps to refute myths and fallacies, for example that masses of white pine grew here, there and everywhere in early days before they were butchered, leaving large areas as scrubland, that sawmill residues never were cause for alarm until recent 'scares' (in fact they were regarded with alarm even before the middle of the last century and appropriate punishments were devised). Sometimes, too, the wanderings of early explorers, like Champlain and Brule, or pioneering efforts in an area, like those of Michael Grass in Kingston, are discussed in connection with their descriptions of the land at the time, and in the process other popular myths are exploded, not having to do specifically with resources or conservation.

The history section has also, over the years, built up a fairly comprehensive listing of floods since the historical period began, and is continually expanding it. The engineering section makes great use of these listings.

In the past year or two the history section has also been asked by some Conservation Authorities to advise on the preparation of a short history of an Authority's activities to date. Probably, as the years pass, this aspect of the section's activities will increase, as past achievements will become part of the historical record.

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An Introduction to Water Pollution Control

ONTARIO
PROVINCE OF OPPORTUNITY

Ministry of the Environment
Hon. J.A.C. Auld, Minister Everett Biggs, Deputy Minister

"We travel together, passengers on a little space ship, dependent on its vulnerable supplies of air, water and soil---preserved from annihilation only by the care, the work, and I will say, the love we give our fragile craft."   Adlai Stevenson.

Foreword

So you're interested in pollution.

We, in the Ontario Ministry of the Environment, are glad to hear it. We know that an informed public is vitally important in the fight for an improved environment. Always remember that governments can proceed only as fast as the people will allow; for this reason it is up to all of us to spread accurate, factual information.

One word of caution: constantly bear in mind that the subject of pollution is very complicated and very technical. For this reason, in even the best treatment of the subject on a concise scale, there is a danger of over-simplification. It is far from a simple matter, and will really require much extra reading on your part. But, if you promise to remember this risk, we will try to put down some basic facts to help in your search for information.

AN INTRODUCTION TO WATER POLLUTION CONTROL

What do you mean by pollution? The Oxford Concise Dictionary says "to pollute is to destroy the purity of; make (water, etc.) foul or filthy." Sounds simple enough, but, curiously, pollution means different things to different individuals, even different things to the same person in different circumstances.

For example, distilled water is surely the purest form of water; yet from the standpoint of a fisherman, a lake filled with distilled water would be 'polluted' because no fish could grow in it. Sea water has salt in it, and the sea fish flourish in it. Yet for many purposes, (drinking, use in engines, or as a medium for freshwater fish), it is polluted.

Pollution is usually associated with man and his various activities, but nature herself causes it too. When leaves etc., fall from trees that overhang bodies of water, organic pollution takes place. Where marshes exist, large numbers of bacteria enter the watercourse as a result of decay of the weeds and reeds. This natural decay may cause high 'coliform counts', which may be wrongly interpreted as indicating dangerous pollution.

The accepted level of coliform count in water to be used for swimming is up to 1000 per 100 millilitres, and this level can easily be exceeded near decaying vegetation. Nature usually can look after her own pollution and can cleanse the waters through the action of sunlight, micro-organisms, (minute forms of life, plant and animal,) and cascades or white-water areas in the rivers.

It is only when man overloads her efficient purifying mechanism that trouble occurs and we face situations which may be unsightly, unpleasant and even dangerous to health. It is also well to remember that, as the number of humans increase on earth, and their intellectual and technological ability grows, the possibilities of this abuse of nature's mechanism becomes more probable.

The pollution of Adlai Stevenson's "fragile craft" can be divided into three general areas, though each in actuality overlaps the others: air, water and soil. For our present purposes, we will limit our discussion to water and perhaps pursue the others later. Again, for our purposes, we will concentrate on fresh water, and even more, limit it to a large extent to surface water (e.g. lakes, rivers, creeks, swamps, etc.).

Bear in mind though, that about forty per cent of Ontario's population take their drinking water from ground water that comes from wells, dug, drilled or flowing artesian. When pollution of this source occurs it is very serious indeed, since the correction of it is all but impossible. It is for this reason that sanitary landfill methods of garbage-disposal are now being watched so closely. Organic matter in this garbage decays or ferments and percolates down to the underground river which carries the ground water, called the "aquifer".

Pollution sources of fresh surface water may then be divided into three main categories:

(1) domestic

(2) industrial

(3) agricultural

The first and second may be carried to the treatment works by sanitary sewers. On the other hand, storm sewers pick up the run-off from the streets and run directly to the natural waters. Occasionally, drains lead directly to the watercourse from the offending source. This is rapidly being corrected.

The third pollution source is agricultural wastes. These are washed from the surface of the land by sheet erosion in spring, or in a heavy downpour in seasons when the ground is bare, or they percolate through the soil to end in the watercourses, or are carried by tiles, drains and ditches to them.

All three types of pollutants can be subdivided into two headings: organic or inorganic wastes. Organic wastes are capable of being broken down into carbon, oxygen and hydrogen by treatment or by natural agents, such as sunlight or oxygen which is dissolved in clean water, and thus are totally changed. Inorganic wastes contain minerals and chemicals: salt, sand, phosphates, nitrates, mercury, chrome, etc. The situation is not as simple as this sounds, because in all three forms of waste both organic and inorganic matter is often present.

High on the list of organic pollutants is the material associated with bacteriological pollution: the fecal or natural body wastes from man and animals. When water contains a high fecal bacteria count, it suggests that disease-carrying organisms may also be present. That is why a high E. coli count, though of itself not necessarily dangerous, indicates possible trouble from intestinal bacteria which may be there and which do carry disease. (Infectious hepatitis, diarrhea, dysentery, typhoid, etc.). Water is classed as "satisfactory" for drinking

purposes with a coliform count of 0 per 100 millilitres.

Bacterial pollution may come from inadequate sewage treatment plants, from unsatisfactory septic tanks, (either operating poorly, or badly situated and drained), or from drainage from farm operations, barnyards, etc. For years the scientist in the laboratory has been able to control this type of pollution with proper sewage plants and chlorine. But inadequate cottage or resort systems, municipalities which dragged their feet about installing sewage systems, and now the new method of raising animals, (hogs, chickens and cattle) in what can only be called animal factories raise problems which must be solved.

Sanitary and Storm Sewers

Sanitary sewers are a system of pipes that carry to the sewage or wastewater treatment plant domestic wastes from toilets, sinks, tubs, and basins; commercial wastes from food-handling and processing; and industrial wastes from factories, etc. The large trunk sewer which collects the flow from the individual establishments is usually located under the centre of the roadway with man-holes to the surface every 250-300 feet.

Storm sewers collect run-off from streets and parking-lots, and from weeping tile and roof drains around buildings and uncontaminated industrial processing waters. The metal gratings at the roadgutters are the inlets to them. Since it is considered that this run-off is primarily rainwater or melting snow, these usually run directly to the watercourse.

At a very few places, however, the sanitary sewers cross-connect with the storm sewers. The main purpose of this 'legal' cross-connection is to provide a safety-valve or overflow for emergency conditions. Such abnormal conditions may result from a blockage in the main sewer or extreme overloading because of intense rainfall. Under such conditions, it is considered preferable to have a weak dilution of sewage diverted with water to the watercourse which has some properties for self-purification or recovery, than to have the same material backing up into basements in the affected area.

Overflow or by-pass facilities are usually provided at treatment plants as relief in case of a long term power or equipment failure or excessive overloading. The use of such facilities is rare indeed, and is usually of short duration. If it does occur, it is during storms or in other conditions when the riverflows are high, thus considerable dilution takes place.

It should be kept in mind that high flows in the sewers to the treatment plant do not result in an overflow of any amount beyond 'normal'. What happens is that the sewage passes through the plant slightly more quickly and the treatment process (biological and chemical) does not have quite as long to operate. This means that all sewage gets less treatment than normal, rather than some getting the usual treatment and the remainder none. Since this occurs only when there is an extra high flow of water, there will then be more natural dilution.

In the Peterborough system for example, there is no place where the reverse process of storm sewers overflowing into sanitary sewers occurs. If this were to happen, it would increase the hydraulic load on the

sewers or the treatment plant. There is the exception of illicit connections of roof leaders, the legal but sometimes excessive contributions from foundation drains (e.g. from new, unsettled house foundation backfilling) or of sometimes excess surface water entering via sanitary manhole tops.

Industrial waste from our factories and plants is a much more complicated question, involving many sophisticated elements, which were not dreamed of when the original plant was built. In some cases the treatment plant can remove these pollutants, in others it can't. In any case it is sometimes more reasonable to handle and treat the industrial wastes in a combined form at the central plant, while at other times separate pre-treatment at the source is preferred.

In Peterborough joint treatment is the most common. The classic case of an element that can't be removed easily from waste-water is phosphorous, present in the form of phosphates. Phosphorous comes from domestic wastes, including detergents, and from agricultural operations. Tertiary treatment, or three-stage plants are being developed now that take it out, and full-scale operating plants will be available soon. Research is being carried out for the removal of phosphorous from sewage lagoons, or as they are now more delicately called, waste stabilization ponds.

Why do we worry about phosphorous particularly? Because it is one of the foods, or nutrients, as they are called, required for the growth of algae. It is in other words, an excellent plant fertilizer.

Algae is the plant micro-organism at the base of the food chain:

the little fish feed on them, the bigger fish feed on the little ones, and man feeds on the big fish. If there were no algae there would be no fish.

Trouble looms when there is too much phosphorous in the water. If circumstances are conducive, an overbloom of algae results. These little organisms wash up on shore, and in the process of decaying, use up the oxygen which is dissolved in the water, making the water useless for other forms of life. During decay the algae are ugly, smelly and actually can be dangerous as they may be poisonous. It is ironic that fertilizers that make things grow can cause the 'death' of a water body. This comes of course from an over-growth of plant-life.

Phosphorous in the form of phosphates comes from four main sources:

(1) excrement in domestic wastes

(2) detergents which contain it 'to make clothes whiter'

(3) ground surface run-off from urban areas

(4) the run-off in spring from farmers' fields which have been fertilized.

Some lakes and rivers, because of their nature, are always going to be rich in phosphorous. If a lake is relatively shallow or if it has a high proportion of natural vegetation either contained in it or falling into it, it will usually receive more phosphorous than seems desirable. Such lakes are our Kawarthas. For this reason, it is doubly important for us to ensure that any artificial additions are removed, as those from improperly treated sewage, detergents, or farms.

It is therefore up to us to assist our Ministry of the Environment

in the campaign to improve the sewage disposal system for the municipalities, industries, cottages and resorts of our area. This will cost you money, and you must do without some luxuries to achieve it, but it is the duty of all of us, as responsible citizens to make this personal sacrifice in order to preserve our natural resources.

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Ontario's Air Pollution Index

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Department of the Environment

Hon. George A. Kerr, Q.C., Minister

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ONTARIO'S AIR POLLUTION INDEX

Air pollution being such a topical subject today, it is desirable for the public to have a day-to-day knowledge of pollution levels and be readily able to compare these levels with those reached during "air pollution episodes". It is well known that such episodes in the past, in other parts of the world, have caused an increase in human sickness and mortality for people with respiratory problems. In Ontario the day-to-day levels are obtained by using an Air Pollution Index, developed by the Air Management Branch as a basis for action in an alert system to control or prevent an air pollution episode.

Epidemiological studies indicate a relationship between the severity of health effects and the degree of air pollution measured by concentrations of particulate matter and sulphur dioxide.

Although extensive data was available for analyses of the concentrations of these pollutants during episodes, there was little information on the concentration of other pollutants. While it would seem desirable to have the Index as a function of concentrations of all pollutants possibly involved, the small amount of data available on other pollutants to use as weighting in an equation made it necessary, for the present time, only to consider sulphur dioxide and particulate matter.

Several other areas have developed air pollution indices, many of them designed for particular pollutants. For example, the Department of Health of Detroit devised an index based only on the coefficient of haze. The index, known as "MURC" (Measure of

Undesirable Respirable Contaminants = 70 x $(COH)^{.7}$) is also used in Buffalo, New York.

An air pollution index used in the Bay Area, San Francisco, is based on oxidants, nitrogen dioxide, carbon monoxide and particulate matter, the latter expressed as the coefficient of haze.

The index, known as the Combined Pollutant Index,[2] has the formula CPI = $2(OX)+(NO_2)+(CO)+10(COH)$ where oxidants and nitrogen oxides are concentrations in p.p.h.m. and carbon monoxide in p.p.m. The weighting given to the constituents, oxidants (200), carbon monoxide (1), nitrogen dioxide (100) and coefficient of haze (10), indicates an emphasis on photochemical smog.

M. M. Braverman and C. Theophil[3] devised an index for New York City based on sulphur dioxide, carbon monoxide and the coefficient of haze. An index designed by M. H. Green[4] based on sulphur dioxide and coefficient of haze has been used for air pollution potential forecasting for Sarnia, Ontario. By defining desirable and extreme levels of SO_2 and COH, Green determined an index for each as follows:

SO_2 index = $84(SO_2)^{0.431}$

COH index = $26.6(COH)^{0.576}$

where

SO_2 = concentration of SO_2 in p.p.m.

COH = coefficient of haze

$$\text{Green's API} = \frac{SO_2 \text{ index} + \text{COH index}}{2}$$

The index for each contaminant is given equal weighting in determining the combined index. Other air pollution indices have been proposed by L. A. Clarenburg,[5] J.F. Clarke and R. B. Faoro,[6] J. C. Fensterstock[7] et al, and T. A. Rich.[8]

Ontario's Index

For reasons mentioned earlier, the concentrations of only sulphur dioxide and particulate matter were chosen to be the basis

for Ontario's Index. Photochemically produced smog, comprising irritating oxidants resulting from the reaction of nitrogen oxides and hydrocarbons, does not occur frequently and thus in most Ontario cities is not as important as the reducing type smog comprised mainly of sulphur dioxide and particulate matter. In fact, both sulphur dioxide and particulate matter have been measured for some time in the industrial cities of the province, and emission surveys have determined the principal sources of these pollutants.

Legislation in Ontario authorizes the Minister of the Environment to order any source not essential to public health or safety to curtail or shut down its operations when pollution levels are reached that could be injurious to health. To make possible the use of the Index as one of the bases of such control, it was designed to relate to pollution levels which could cause severe health effects like those during air pollution episodes.

The other basis of control is a meteorological forecast indicating the potential persistence of high pollution conditions.

Sulphur Dioxide and Particulate Matter

To determine whether sulphur dioxide measurements could be used to indicate particulate matter, an attempt was made to correlate readings of SO_2 and COH readings. The correlation coefficient between the measured values was found to be quite low, especially during winter months when air pollution is an important factor in the development of an episode. Following are the correlation coefficients for each month:

$r_{Nov} = 0.29$; $r_{Dec} = 0.14$;

$r_{Jan} = 0.06$; $r_{Feb} = 0.31$

A similar, poor relationship was obtained for daily average sulphur dioxide concentrations and high-volume sampler measurements. The low correlation indicated that sulphur dioxide cannot be used to indicate particulate matter, and the Index must be a function of both sulphur dioxide and particulate matter concentrations.

Sulphur dioxide is measured directly by continuous analyzers and there is no difficulty in telemetering the levels of this pollutant from remote field stations to the Air Management head office.

The suspended particulate matter, however, presents a problem. At present there is no method of measuring the concentrations of this pollutant directly for the periods of time desired and telemetering the measurements so that they are known on a real time basis.

At present, the techniques in Ontario involve the use of the Hemeon paper tape sampler and the high-volume sampler. The latter method provides concentrations in the desired units, $\mu g/m.^3$ The sampler draws a large volume of air (60 cubic feet per minute) through a filter paper for 24 hours. Measurements are obtained by weighing the filters in a laboratory before and after exposure. The data cannot be telemetered on a real time basis.

The Hemeon paper tape sampler can be set to provide hourly readings which can be telemetered. Air is drawn through a portion of a filter paper tape. The tape is automatically advanced to a new position after each sampling period. The fundamental basis of evaluating the sample is optical. The transmittance of light through both filter and deposit is compared with the transmittance through a clean portion of the filter.

The difference in transmittance is converted into units of "coefficient of haze" (COH) per thousand linear feet of air passing through the filter. A COH unit is defined as that quantity of light scattering solids on the filter which produces an optical density equivalent to .01 when measured by light transmission.

It is obvious that the COH measurements will not only depend on the amount of particulates in the air deposited on the tape, but also on the size, shape and opacity of the particulates. Each location will thus have a different relationship between the COH value measured and the true concentration of the particulates.

With measurements of COH representing particulate concentrations in the equation, the Index will differ for each community. However, by the method of design, the significance of Index levels will be the same. With respect to the size of the particles obtained by the tape sampler, Dr. W. J. Ingram[9] determined a high correlation with COH values and the number of particles in the size range affecting the respiratory system.

The Design of an Index for Toronto

The relationship between the high-volume sampler data and COH values was determined for Toronto, as graphed in Figure 1. For comparison purposes, the relationship as determined for a New York station by Dr. Ingram is also shown.

For Toronto:

$HI\ VO = 240(COH)^{.91}$ where HI VO = suspended particulate matter concentrations in $\mu g/m^3$

COH = coefficient of haze/1,000 linear feet of air

The correlation coefficient for the above relationship is .70.

Data for sulphur dioxide and suspended particulate matter during air pollution episodes was obtained from summaries of epidemiological studies given in references #10, #11, #12 and #13. The data plotted in Figure 2 indicates the variability of the combinations of concentrations which occurred during the episode. An analysis of the data revealed the following pairs of values could be used as the threshold to a severe episode at which the Air Pollution Index is set to equal 100:

1. Suspended particulates 600 $\mu g/m^3$ which for Toronto is equivalent to 2.74 COH and sulphur dioxide .13 p.p.m.

2. Suspended particulates 500 $\mu g/m^3$ equivalent to 2.24 COH and sulphur dioxide .25 p.p.m.

Setting the equation for the Air Pollution Index as a function of the 24-hour average concentrations of SO_2 and COH as follows:

$$API = A(COH) + B(SO_2) \qquad (2)$$

The weighting to be given for each pollutant may be determined by setting API at the threshold level of an episode equal to 100 and substituting the foregoing given pairs of values for the 24-hour average concentrations of COH and SO_2. Equation (2) can be solved for A and B becoming:

$$API' = 30.5(COH + 126.0(SO_2) \qquad (3)$$

For a desirable scale the API was made to be an exponential function of API', that is, $API = C\left[API'\right]^D$

$$API = C\left[30.5(COH) + 126.0(SO_2)\right]^D \qquad (4)$$

The levels of coefficient of haze and sulphur dioxide set by Ontario Regulations as objectives are 24-hour averages of COH at 1.0 and SO_2 at .10 p.p.m. Setting API = 32 at these levels provides a range of indices twice as great, that is, from 33 to 100, for control action to take place than for the range of acceptable levels, 0 to 32. Substituting API = 100 for levels of COH and SO_2 given above and API = 32 when COH = 1.0 and SO_2 = .10 equation (4) can be solved for C and D to give the equation for the Air Pollution Index for Toronto as follows:

$$API = .2\left[30.5(COH) + 126.0(SO_2)\right]^{1.35}$$

Figure 2 shows the boundaries for API equal to 100 and 32 as well as for 50 and 75. Figure 3 illustrates the levels of the Index and describes effects of the pollution during a number of episodes. High pollution levels persisted during these episodes for more than one day. Setting the Index at 100 based on 24-hour averages, provides a margin of safety for action to take place before the severe effects of air pollution can take place.

The report by L. J. Brasser et al[12] noted that the number of days on which pollution levels remained high had a very marked effect on the severity of the episode. Temperatures were also a factor affecting the daily mortality increases. Most of the severe episodes with increased mortality occurred during the winter. For this reason, the relationship between high-volume samples and COH data was based on winter data only (November to March).

An Air Pollution Alert System

An Air Pollution Index of less than 32 is considered acceptable. At these levels concentrations of sulphur dioxide and particulate matter should have little or no effect on human health. At the Advisory Level at which the Air Pollution Index = 32, and meteorological conditions are expected to remain adverse for at least six more hours, owners of significant sources of pollution in the community in which this Index occurs may be advised to prepare to curtail operations.

The "First Alert" occurs when the Air Pollution Index reaches 50 and meteorological forecasts indicate high pollution potential conditions for at least six more hours. Owners of major sources may be ordered to curtail operations.

P. J. Lawther[14] reported that patients with chronic respiratory disease may experience accentuation of the symptoms during SO_2 levels of .21 p.p.m. and particulate levels of 300 $\mu g/m^3$ corresponding to 1.3 COH. At this level the Air Pollution Index is equal to 58. This evidence as well as studies by B. W. Carnow et al[15] formed a basis for the proposed "First Alert" at 50, which incorporates a safety factor.

If the abatement action does not succeed to lower the levels of the Index, the "Second Alert" will be issued when the Index of 75 is reached and high pollution potential conditions are forecast for at least six more hours. Further curtailment of operations of sources producing emissions of pollution will be ordered.

At the "Air Pollution Episode Threshold Level" at which the Index reaches 100 and is forecast to continue for at least six more hours, owners of all sources not essential to public health or safety will be ordered to cease operations. At this level the conditions could have mild effects on healthy people and seriously endanger those with severe cardiac or respiratory disease.

Index Performance

The Index went into effect in Toronto on March 23, 1970. During the first year of its operation, the A.P.I. exceeded 32 on 26 occasions. Advisories to selected industries were issued by the Air Management Branch. On 2 of these occasions, August 14 and October 8, 1970, the Index exceeded 50 and industries were ordered to curtail emissions by the Minister. The maximum Index was 56 on October 8.

The Index is gradually being expanded to other cities in the province. It went into operation in Hamilton on June 15, 1970; Sudbury on January 15, 1971; Windsor on March 19, 1971.

Grey Cup Smog 1962

In retrospect the highest Air Pollution Index occurred in Toronto during November 30 to December 4, 1962, with the level reaching a peak reading of 155 during the evening of December 1, 1962 and 125 during the early morning hours of December 4, 1962. (See Figure 5).

Very light winds with temperatures ranging from 34 to 50 degrees and relative humidity of 10 per cent prevailed throughout most of the period.

However there is no recorded medical evidence of an increase in hospital admissions of people with respiratory illness during this period.

This evidence indicates that the planned action authorized at an Index of 100 provides a safety factor with regard to the prevention of a serious air pollution incident.

Summary

The Air Pollution Index has been designed for use as the basis of an Air Pollution Alert System. Where the Index has been in

operation, owners of pollution sources have co-operated in decreasing their emissions when advised that levels of the Index were near or approaching the 32 level. These actions have helped maintain lower levels of pollution. In all areas, permanent, pollution abatement programs are in progress which should prevent future high Index levels.

The Index equation differs from place to place according to the relationship between particulate matter concentration, expressed in weight per unit volume of air, and the measure of coefficient of haze. The design method followed, however, ensures that Index values have the same significance for each community.

The equation for the Index could be readily modified to relate directly to concentrations of suspended particulate matter, should an instrument become available capable of directly measuring and telemetering particulate concentrations on a continuous basis in the size range desired.

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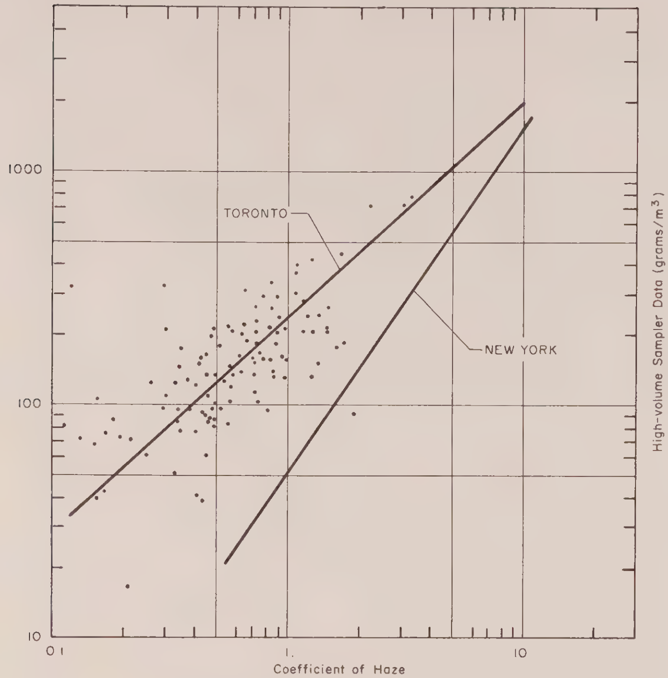

FIGURE 1: Relationship between the coefficient of Haze and high-volume sampler data for Toronto and New York

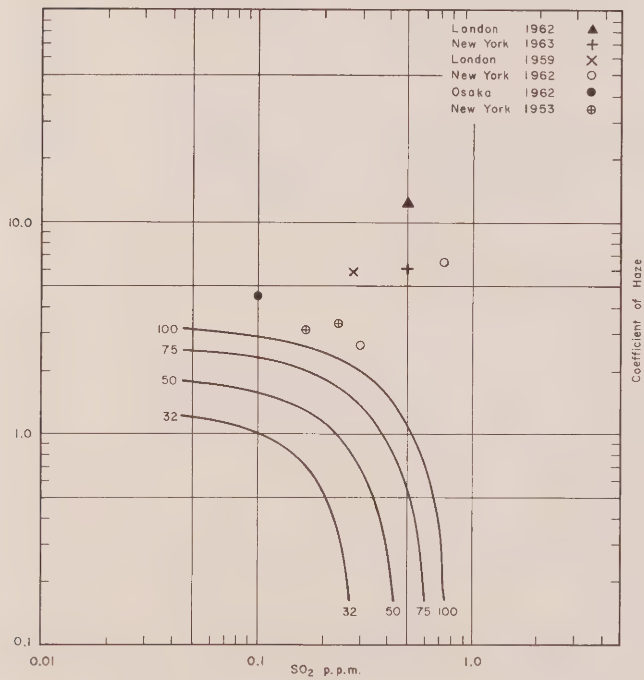

FIGURE 2: Air Pollution Index boundaries for values of 32, 50, 75 and 100 with episode levels plotted.

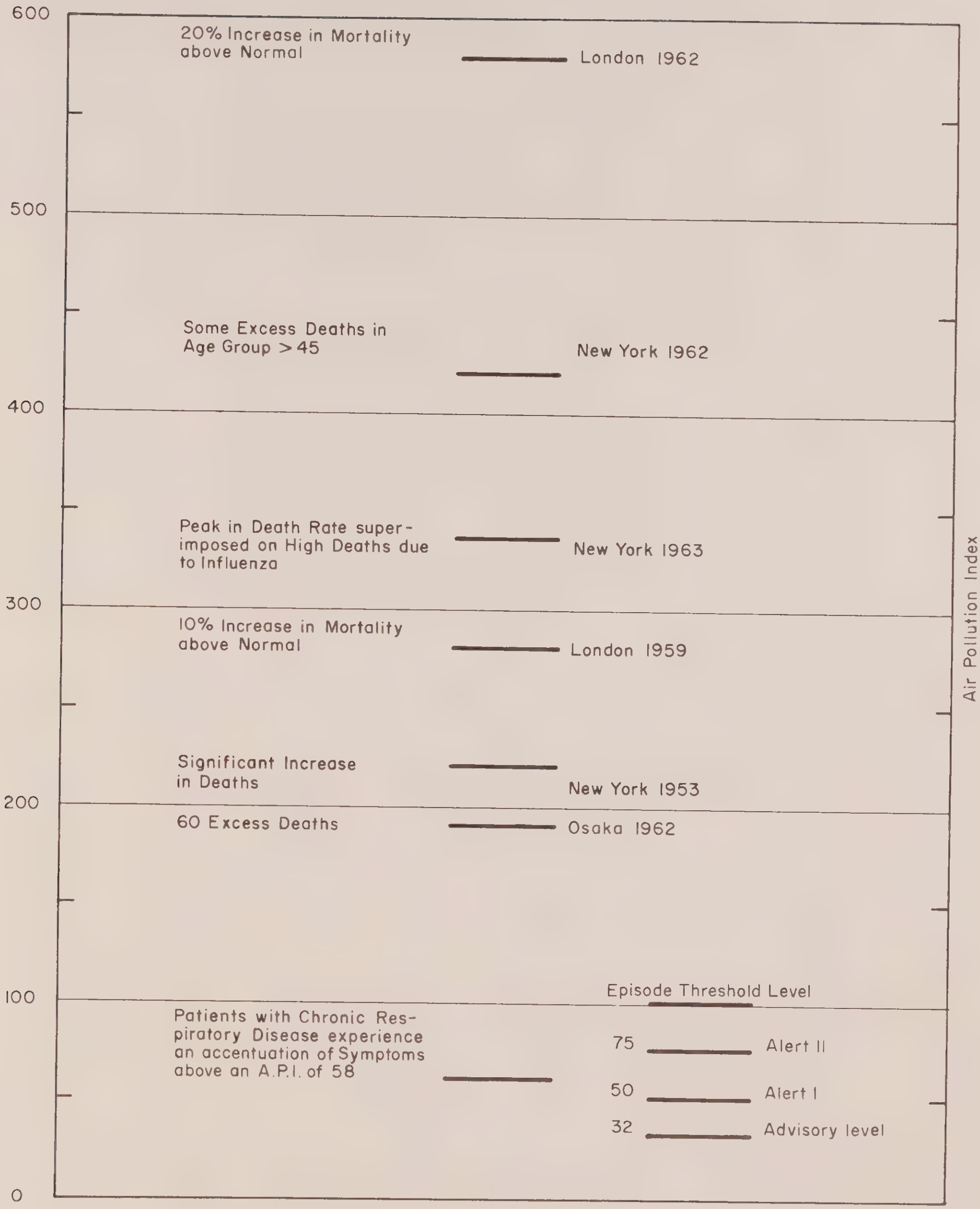

FIGURE 3: Levels of the Air Pollution Index during episodes and Ontario Alert System.

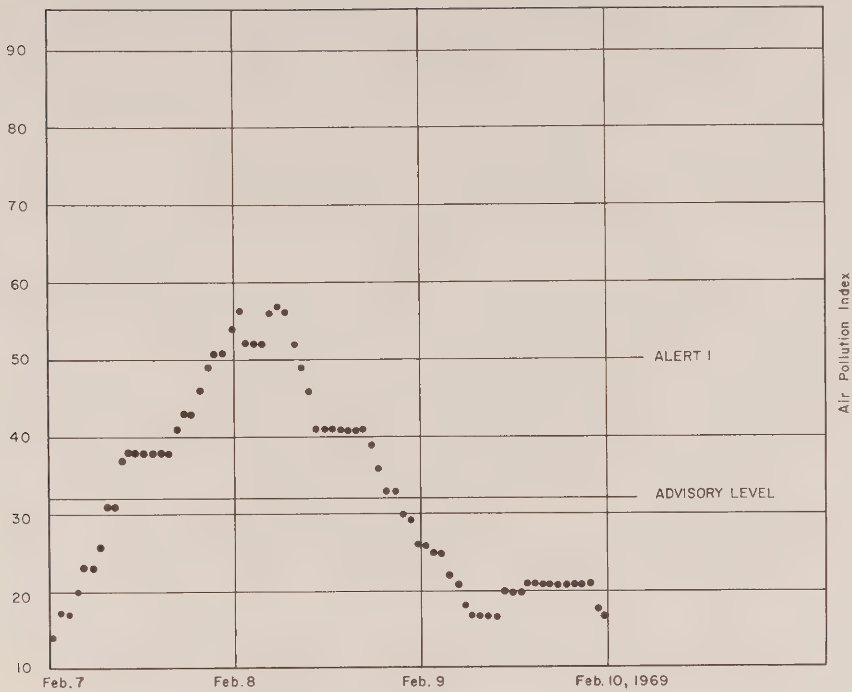

FIGURE 4: Index for period of highest pollution levels in Toronto during 1969.

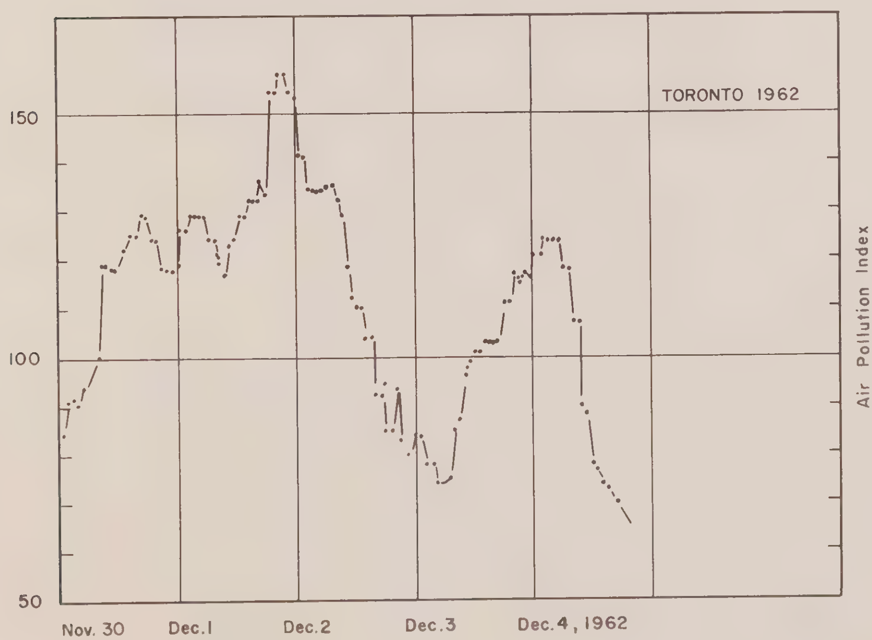

FIGURE 5: Air Pollution Index for period of highest pollution levels in Toronto.

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Waste Management and Public Health

Ontario

Ministry of the Environment

Hon. J.A.C. Auld
Minister

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Deputy Minister

WASTE MANAGEMENT AND PUBLIC HEALTH

What is waste?

One definition describes waste as any material which the owner considers will cost him more to keep than to discard.

This warrants detailed examination.

First, the cost is not necessarily purely monetary; it may comprise a penalty in terms of time or effort, or of nuisance or hazard, including health hazards.

Second, these values may, and often do, vary. What is considered waste one day may be prized as a valuable commodity on another.

Third, the decision, conscious or unconscious, whether material is waste or not is an individual one made by the owner. Until recently, consideration of the cost to the community or the environment of discarding waste was not taken into consideration.

It is also important to note that this definition says nothing about the intrinsic value of the material; only about its value to the owner.

There is one particular waste which may be considered an exception, since its discard is, largely, involuntary; human bodily wastes

- sewage. The health hazards resulting from the improper disposal of sewage have been recognized for many years. Wastes, other than sewage, can be separated into six major classifications, with widely differing hazards, problems, and solutions, which will be considered in greater detail at a later stage. They are:

1. municipal and industrial solid wastes
2. liquid industrial wastes
3. hazardous wastes
4. agricultural wastes and sewage sludge
5. abandoned automobiles
6. litter

Another question which deserves examination is what is meant by waste management?

Waste management must include the complete system of storage, collection, transportation, treatment and disposal of waste. The individual elements of the system are intimately interlinked and cannot be dealt with in isolation.

Moreover, the management of waste may well have to take into account some of the questions raised in the definition of waste - whether a community can afford to accept without question the decision of the owner of the material; or, for example, whether the original manufacturer of the product should not be responsible for considering in its manufacture the problems which may be involved in its handling and disposal as waste.

It is earlier noted that the problems of one waste, sewage, have been recognized for many years. It is only comparatively recently that the public have become aware of the problems involved with other

wastes, though they are now making up for lost time. There are a number of reasons for this, but three in particular should be observed.

First, though improper management practices can result in health hazards, these are generally not infectious, not transmissible, and the relation of cause and effect is less obvious.

Second, until comparatively recently in North America, the urban-rural interface was well defined, and the wastes from a city could be transported beyond its boundaries for disposal in a relatively sparsely populated area. Urbanization has now progressed beyond the boundaries of the cities and may extend for many miles into formerly entirely rural areas. Land area is therefore at a premium and land use planning usually neglects to consider requirements of waste management.

And third, the increase in packaging, and disposable convenience merchandise, compounded by the increase in population and its concentration in urban areas, has vastly increased the volume, variety and hazard of materials which must be handled and disposed of.

Before dealing with the waste classifications and their individual problems, the public health aspects of waste management, at least as they are seen in Ontario, should be examined.

There are two relatively distinct problems involved.

One: Direct health hazards, vectors of disease, air and water pollution, or gas generation, for example;

Two: Matters of general public health concern in the broader sociological concept of the term.

Usually, direct hazards can be minimized and often eliminated by the proper management of existing practices. New practices, before being introduced, can readily be assessed to ensure that direct hazards will not be introduced.

Waste management legislation in Ontario was designed primarily to do this.

The broader aspect is a very much more complex problem with implications which reach far beyond the jurisdiction of any one government agency, and whose solution may require measures that will be radically different from present approaches.

Municipal and Industrial Solid Wastes

This classification includes domestic and commercial refuse together with non-hazardous solid industrial waste. It is generally collected and disposed of under the control of the municipality where it is generated.

On the average, this type of waste can be expected to comprise about 50 per cent paper and paper products, 15 to 20 per cent organic waste or garbage, between five and 10 per cent metals and approximately the same quantity of glass, between five and 10 per cent ashes with the remainder, usually about 10 per cent, which can only be termed miscellaneous since it may include almost any substance imaginable. The actual composition varies from day to day, as does the moisture content, and this variety, and its heterogeneous character, make it an engineer's nightmare.

Public health aspects may conveniently be separated into two sections, occupational hazards to workers, and hazards to the general public.

Studies on occupational hazards have generally been related either to municipal refuse collection workers or to accidents to workers in the treatment and disposal operations.

Arthritis and cardiovascular diseases appear to be occupational hazards of refuse collectors. A high incidence of muscle and tendons disease, particularly affecting the back, is also prevalent and there is evidence that the same comment may apply to skin diseases. Hernia may also be considered an occupational hazard. Generally, sanitation workers have an extremely high injury frequency rate, injuries to the hands being most common.

For those with a passion for odd statistics, Dr. Sliepcevich, who carried out one of the most extensive studies, estimated that the amount of daily lifting by the average refuse collection is equivalent to raising a full garbage can weighing 35 pounds to the top of the Empire State Building.

The use of paper or plastic bags rather than garbage cans will tend to reduce these hazards, but much greater attention must be paid, in the design of collection vehicles and collection systems, to the need for a reduction in the manual effort required by collectors.

The open dump is the most primitive method for disposal of municipal waste, and is usually associated with open burning of the garbage to reduce its volume and, hopefully, its attraction to rodents.

All dumps, whether open burning is practiced or not, provide breeding grounds for rodents, flies and other vectors of disease. In some areas they provide attractive feeding grounds for other animals, particularly bears. From the point of view of air pollution, the gaseous effluent from burning garbage includes inorganic compounds of sulphur, nitrogen and carbon; prominent organic constituents are aldehydes, organic acids and esters; fats and fatty materials, phenols, and polynuclear hydrocarbons. The particulate matter may be either organic or inorganic, and may be impregnated with acids. While all of these may have some public health implications, they are probably small in relation to the discharge of similar elements from other sources. A more specific hazard, which has already resulted in a number of serious accidents, is the loss of visibility due to the smoke from burning dumps being carried across highways.

Since dumps are generally located without any consideration of pollution problems, they are very frequently found adjacent to, or even in, water courses which may be grossly contaminated as a result. Organic material, soluble salts, and alkalis can cause serious degradation of the water quality.

A more serious problem from the public health aspect is the possibility of leaching of these materials into ground water particularly if dug wells are used for water supply in the vicinity. Any hazard which may result will usually be due to soluble salts, since the organics and the associated micro-organisms are virtually eliminated by a comparatively short period of percolation through the soil.

An interesting side light on burning dumps is the fact that tissues of wild rats living in the vicinity of refuse dumps generally have a much higher lead content than those of rats reared in the laboratory, and associated with this higher lead content is a high degree of incidence of nuclear inclusions and carcinomas in the kidneys. This was ascribed by the investigators to continous exposure to smoke emanating from the smoldering refuse in the dump in which the rats lived.

Waste management legislation in Ontario does not permit this method for the disposal of waste except for very small communities in remote areas, and even where it is still permitted, certain basic requirements are laid down to minimize the possibility of health hazard and environmental pollution.

Almost all of the problems discussed to this point can be virtually eliminated by careful selection of the area in which the site is to be established, and by carrying out the operations using the techniques of sanitary landfill. Essentially, this means that the waste is deposited under controlled conditions with compaction into a cell and covering with a least six inches of compacted earth at regular intervals, preferably daily.

While research is undoubtedly necessary to find quantitative data on the movement of contaminants in leachate through the sub-surface and in the watertable, particularly with regard to reduction of concentration by such mechanisms as ion exchange, and dilution by dispersion, adequate qualitative data is already available from which the location of the site, to minimize pollution problems, can be made with confidence. The main thrust of present research programs is to develop more accurate

information so that doubtful locations, now unacceptable, can be utilized with adequate precautions.

Two comparatively new developments are coming into use for the pre-treatment of waste prior to sanitary landfill, principally to reduce costs and the volume of waste, but which also make it easier to minimize nuisances such as blowing papers. Grinding the waste to a common particle size has many advantages and is being closely investigated by the Ministry of the Environment as having potential wide application throughout Ontario. One such plant is already in use. Packing and baling involves compression of the waste to a comparatively high density bale which is then bound together. It has some advantages in the operation of a landfill site, but its principal application may be to reduce the cost of transportation, particularly if rail haul can be utilized. However, neither of these methods eliminates the necessity for careful location of the site to minimize the problem of leachate entering ground or surface water.

One possible major health hazard has not yet been touched upon, and must be given very careful consideration whether pre-treatment is used or not. During the decomposition of the organic material in garbage, a number of gases are generated, the most significant of these being carbon dioxide and methane. Since decomposition continues in the landfill site for many years, gas continues to be generated over that period.

Carbon dioxide is principally of concern if, in entering the watertable, it dissolves minerals which may degrade water quality. In one instance, due to probably unique circumstances, carbon dioxide entering basements of houses adjacent to a landfill site have caused a serious

health hazard, but it is most unlikely that this incident will be repeated.

Methane is of greater importance primarily because of its combustibility, and since an explosive mixture can be formed when mixed with air. Strict control should therefore be exercised over the uses to which a disused landfill site can be put. The Environmental Protection Act of Ontario provides this control for a period of 25 years. Precautions can be taken to eliminate the hazard of gas entering buildings constructed on landfill sites, but great care is required, extensive engineering works may be necessary, and single family residential development should not be permitted under any circumstances. Preferably, completed landfill sites should be developed as park or recreation areas.

Two points should be emphasized. First, a properly located and operated landfill site will virtually eliminate both health hazards and contamination of the environment. Second, disposal onto land must ultimately be utilized for some proportion of the total waste, irrespective of how the waste is treated, whether by incineration, reclamation, or any other methods that may become available in the foreseeable future.

The emission of contaminants from the incineration of municipal waste, can be very substantially reduced by suitable incinerator controls, but it is important to recognize the limitations, and the consequences of implementing them. For example, an electrostatic precipitator will remove a very high proportion of the particulate matter, and scrubbers can be installed to remove sulphur dioxide, and other chemical systems to remove other gases, but at extremely high relative cost. Moreover, to a large degree, all that is being achieved by such measures is to change the air effluents back to the solid state, converting them once again to

water and land pollutants.

The cost of such controls can be reduced if it is practicable to utilize the heat development either to produce steam for district heating, or electricity. However, very substantial problems are involved, and it appears at present unlikely that any such approaches will be found practicable in North America except in specific limited circumstances, for example to serve a large compact high density development, possibly in association with improved handling methods for the refuse such as vacuum collection.

It cannot be emphasized too strongly that incineration does not eliminate waste disposal problems. A landfill site must be associated with every municipal waste incinerator, for the disposal of solid residue and the comparatively large proportion of municipal waste which for various reasons cannot be incinerated. A landfill site for this purpose may require as careful location and operation as one used for untreated waste. Metallic residues which have been identified incinerator ash include copper, lead, zinc, cobalt, cadmium, and chromium, manganese, nickel and arsenic. Further investigation is required to determine whether special problems may arise due to the concentration and the physical state of such material at an incinerator ash disposal site.

It will be obvious from the above that it is not possible to make a general statement that incineration is better than landfill or vice versa, and in fact the same comment applies to any other method of treatment or disposal of waste, existing or proposed. The selection of the "right" method will be dependent on the circumstances of each indi-

vidual case, taking into account all of the factors involved including the degree of air, water and land pollution, health hazards, sociological factors, and of course cost, not only in terms of dollars and cents, but including the use of resources, and of energy, which in turn has a resource use and pollution penalty.

One other basic technology for waste disposal should be noted at this point, although its use in North America is at present extremely limited. This is the composting of organic wastes, with which is usually associated, to a greater or less degree, the salvaging of some of the more readily reclaimable materials such as metals and glass.

Although composting has seen very limited use in North America, and at present only a few units are still in operation, the principal reason is the difficulty of finding markets for the material produced, which is essentially a soil conditioner with very little fertilizing value. However, it has been intensively investigated in Europe, and firm data are available on many public health implications.

Whether windrow composting or mechanical composting is used, the public health implications hinge largely on one critical factor, the temperature to which the treated material is raised, and the duration of its exposure.

In any properly controlled process, the likelihood of survival of pathogens, or of fly larvae and eggs, appears to be remote. The same comment may apply to many resistant forms of parasites, though some doubt exists as to whether it is also applicable to pathogenic fungi.

These observations apply essentially to the finished product.

Some aspects of the plant operation and the process effluents require further investigation. Of course, the sources of the waste must be checked to determine accurately the composition of the material being handled, and the process operation carefully examined to determine the mode of dispersal of contaminants in the surrounding environment. For example, hazardous industrial wastes should obviously be excluded, and care must be exercised in accepting institutional wastes, such as pathological waste from hospitals. Greater care would need to be exercised if undigested sewage sludge was to be composted with the organic municipal waste, or if a concentration of pesticides and herbicides was anticipated.

If manual separation of reclaimable material forms part of the process, very careful controls are necessary to safeguard the health of workers.

A number of other approaches are being investigated - pyrolosis, fluid bed incineration, wet oxidation, biological fractionation, and a number of alternative techniques for the development of municipal reclamation plants. None of these developments is at the stage where they can seriously be considered as an alternative to presently available methods of treatment or disposal. Moreover, it cannot be repeated too frequently that all wastes will require ultimate disposal into one of the sinks - air, land, or water - with resulting pollution problems and health hazards which must be carefully investigated. As an example, the reclamation of newsprint separated from municipal waste is commonly assumed to be associated with a de-inking process so that the fibre can be re-used for the same purpose. Consideration of the practicability of

such a process will include not only the examination of cost, and effect on the forest industries and pulp and paper companies, but must take into account the water pollution which will inevitably result, the disposal of the solid wastes from the plant, and the energy requirement for the process, which itself has environmental implications.

The second major classification of waste with which we are concerned is liquid industrial waste.

The bulk of the waste produced in this category has a limited degree of potential hazard, comparable to that resulting from municipal and industrial solid waste. However, since it is liquid, its disposal onto land is undesirable for two principal reasons.

First, the possibility of run-off to surface waters or percolation to sub-surface aquifers is very considerably increased, and consequently suitable areas for disposal are very limited. Secondly, it is undesirable to utilize a sanitary landfill site for its disposal except in very limited quantities, since it may result in serious operational problems. Moreover, sanitary landfills are normally designed deliberately to reduce the quantity of liquid which will percolate through the waste. An exception might be the use of a completed municipal waste disposal site with a substantial depth of waste and under-drainage which will collect leachate for treatment.

The best solution to this particular problem is the establishment of central treatment facilities which due to the economies of scale can provide the pollution control equipment necessary, but which would be exorbitantly expensive if provided by each industry producing the waste.

Such a plant will be available in the near future to serve the Toronto Centered Region. Three major treatment streams will normally be necessary - thermal decomposition, chemical and physical processing, and biological oxidation. The sludges resulting from the processing may be incinerated or landfilled, as appropriate.

A plant of this type, since it incorporates the various treatment streams, can reasonably provide much more complete treatment and minimize contamination.

A major problem arises from various processes which result in very large quantities of dilute soluble salts. A good example is the brine displaced from the formation of underground gas and oil storage caverns. In areas where it is practicable, discharge into suitable underground formations by a deep well is a reasonable interim solution.

However, this should only be permitted under strict controls, with adequate monitoring to ensure that there are no detrimental effects. Suitable underground formations are limited both in geographical extent, and in their capacity to receive waste. In fact, they represent a resource which should be conserved by requiring surface treatment of all practicable wastes.

Classification of hazardous wastes is restricted to those where a direct and significant hazard of fire, explosion, poison, or radioactivity may result, although in some instances biological and ecological effects must be taken into consideration.

In comparison to the other waste classifications, the quantities involved are usually very small, and practices can be considered

for treatment and disposal which would be out of the question for general wastes.

One such method, for example, consists of sealing the material within a small container which, in turn, is placed in a larger container such as a 45 - gallon drum and the annular space filled with concrete. The drum is then buried in a suitable location, usually in an impermeable clay soil. If treatment is not feasible, permanent containment by this, or other means, is the only reasonable alternative at present.

Falling into this category would be some elements of institutional and hospital wastes. These would include waste pharmaceutical materials, such things as disposable hypodermic needles and syringes, and pathological waste.

Despite the substantial health hazard which is undoubtedly associated with materials in this classification, there have been surprisingly few incidents resulting in injury. The producers of these wastes are usually well aware of the risks involved, and are sufficiently responsible to supervise the handling and disposal procedures and ensure that they are carried out with minimum hazard.

A major concern of the Ministry of the Environment at present is in the development of early warning systems so that full investigation can be made in advance of all potentially hazardous materials, and means developed for their safe handling and disposal. It is obviously undesirable to be forced into the position of having to make complex technical decisions without adequate supporting data and under, usually, intense public pressure. No doubt examples will come to mind readily -

DDT, phosphates, cyclamates, mercury, PCB's, and a number of others are looming on the horizon.

Very close co-operation between public health authorities and the agencies responsible for the protection of the environment is always of mutual benefit; in this particular connection, it is absolutely essential.

The fourth major category of waste comprises agricultural waste and sewage sludge.

Agricultural waste which is produced and disposed of as part of normal farm operations is not of concern.

What is of ever increasing concern are the pollution and public health problems resulting from production of vast quantities of manures from feed lots, piggeries, and confinement operations particularly for egg production. These are not, in fact, farms but factories, and should be treated in the same way as any other industry which abuses the environment.

Traditionally, waste in this category, which is purely organic, has been disposed of by spreading onto fields as a soil conditioner. In limited quantities, and providing common sense precautions are taken, this is of little concern. However, as the quantities involved increase and the area of land available for disposal decreases, major public health and environmental problems result.

Manures from these highly concentrated operations contain elements which if they are leached into ground or surface waters may consti-

tute a localized concern for public health. The major problem results from the oxidation in the soil of organics to nitrogen compounds, high levels of which in water supplies may have direct public health implications, and certainly contribute to eutrophication of surface waters.

While the manures also contain elements such as arsenic, manganese and zinc, the concentrations are very low and unlikely to result in a hazard to public health.

Associated generally with agricultural operations, but normally grouped with the previous category of wastes, are herbicides and pesticides. Greater attention should certainly be paid not only to the use but to the disposal of these materials and of empty containers.

Digested sewage sludge poses a very limited hazard, providing the sewage plant operation is carefully controlled. Local problems, however, may arise, particularly if the sewage treatment plant deals with disproportionately large volumes of industrial waste.

The remaining two categories, abandoned vehicles and litter, have very limited health implications. Broken glass in litter, particularly on beaches, is obviously dangerous, particularly to children, and the snap-off rings on cans with aluminum tops have sharp edges which may also result in cut feet.

It is anticipated that measures will be taken very shortly in Ontario which will adequately deal with both of these categories of waste.

By good housekeeping, and the utilization of existing technology, the possibility of public health hazards resulting from the handling or disposal of wastes can be virtually eliminated. Legislation

now in effect in Ontario, under The Environmental Protection Act, is entirely adequate to ensure this, and to do it without imposing an undue financial burden upon either municipalities or industries.

This may not continue to be the case, and even now such a statement may not be valid if the public health is defined to include the wider, sociological aspects.

There is no question that any waste management problem becomes a very highly charged emotional issue to members of the public involved. Noise, odours, increased traffic, the alleged reduction of property values resulting from waste disposal operations, littering, and similar factors undoubtedly add substantially to the other stresses of modern living. While they are not subject to quantitative analysis, nevertheless these qualitative considerations may exert a profound effect on the technology which can be utilized, on land use, upon the methods and costs of waste collection and must be taken into consideration in any complete system planning.

Re-use, recycling and recycling and reclamation will provide the only rational ultimate solution to these problems of waste management, not primarily to conserve resources, although this will be a valuable bonus, but as the only foreseeable means of keeping within reasonable limits the cost to the public.

This publication was prepared by Wesley Williamson, B.Sc., P. Eng., Assistant Director, Waste Management Branch, Ministry of the Environment.

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Meteorological Aspects of Air Pollution Control

Ontario

Ministry of the Environment

Hon. J.A.C. Auld
Minister

Everett Biggs
Deputy Minister

METEOROLOGICAL ASPECTS OF AIR POLLUTION CONTROL

Introduction

Meteorological factors greatly affect the amount of pollution present in the atmosphere. Temperature and solar radiation, by their influence on the amount of space heating required, affect the quantities of pollutant emitted. Sunshine is required for the photochemical production of oxidants that form smog. Wind velocity, turbulence and stabiltity affect the transport, dilution and dispersion of pollutants. Rainfall has a scavenging affect by washing out particles in the atmosphere. Finally, humidity is a frequent and important factor in determing the effect of pollutant concentrations on property, vegetation and health.

In view of these effects, meteorologists are involved in the following aspects of air pollution control:

1. Forecasting air pollution potential for air pollution control agencies that they may alert industry to carry out temporary abatement action.

2. Selecting sites and designing emission systems for large industrial sources.

3. Establishing air monitoring surveys.

4. Carrying out research in air pollution control methods.

Classes of Pollution Sources

Urban sources of pollution are divided into two classes:

1. Low level emitters - vehicles, combustion sources for space heating of houses and small commercial buildings, privately owned incinerators.

2. High level emitters - stacks serving municipal incinerators, industries and central heating systems for industrial, commercial and institutional multi-building complexes. These stacks are at least 50 meters high.

Meteorological parameters affect ground or "living" level concentrations of pollutants from these two classes of emitters in different ways. In order to provide satisfactory forecasts of air pollution potential for a given area, its micrometeorology and topography must be known in addition to the locations and characteristics of its principal sources of pollution.

Meteorological Factors Affecting Pollutant Concentrations

Meteorological parameters having the most important influence on the diffusion of pollutants in the atmosphere are wind direction and speed, turbulence, temperature and stability.

Wind

Equatorial areas of the world receive more radiation than polar areas. As a result, there is a constant heat transfer from equatorial areas to polar areas to maintain a heat balance. This thermal driving force is the main cause of atmospheric motion or wind over the earth.

In addition, the unequal heating of land masses versus oceans, the effects of mountain slopes facing the sun, etc., also produce air at different temperatures that in turn result in winds because of pressure differentials.

Wind is air in motion in three dimensions. Only the horizontal component, however, is usually considered in terms of direction and speed.

Wind Direction

Wind direction changes with height, normally veering a few degrees (clockwise) depending on the roughness of the terrain. It is always defined as the direction from which the wind is blowing. The "prevailing" wind is defined as the direction from which the wind is most frequent in a given locality. Wind direction indicates direction of travel of pollutants.

Wind direction and its persistence is a very important factor in predicting the air pollution potential of an area in which the principal pollutant sources are high stack emitters located close together. Wind direction is less important where low level emitters cause most of the pollution,

Expected persistence of wind direction, related to topographic features and location of receptors, must also be considered both when forecasting air pollution potential and selecting sites for plants.

Where the principal pollution source is located on a lakeshore,

for example, high air pollution potential conditions can be expected only when persistent on-shore winds are forecast. For a city such as Sarnia which has most of its large industry located to the south, pollutant concentrations are high only when persistent southerly winds occur.

Topographical features such as valleys cause winds to persist in certain directions at much greater frequencies than others. Obviously, such localities should be avoided as sites for large industries.

Wind Speed

Wind speed determines the travel time of pollutants from a source to a receptor. Wind speed also has a dilution effect. Pollutant concentrations downwind from ground level sources are inversely proportional to wind speed. Air potential forecasts for most large urban areas where low level emitters are the principal sources of pollution include light wind speed as one of the criteria.

This dilution effect is not true for hot emissions from high stack sources. In these instances, an increase in wind speed lowers the plume rise, thus tending (up to a point) to increase ground level concentrations. There is a "critical wind speed" for each stack design at which concentrations downstream reach a maximum.

Turbulence

High frequency fluctuations in the wind are known as turbulence and they occur in both vertical and horizontal components. These random motions are responsible for the movement and diffusion of

pollutants about the mean wind path.

Mechanical turbulence is caused by roughness of terrain -- trees, shrubs, buildings, etc.

Thermal turbulence is due to the earth's surface being heated by the sun. Thermal eddies develop as the air, heating up at lower levels first, becomes less dense and rises. Turbulence or vertical motions are at a maximum during the day and at a minimum during the night.

Temperature and Stability

The temperature of the lower region of the atmosphere (surface to 2 km) can either decrease or increase (inversion) with height depending on the character of the underlying surface and the radiation at the surface. The amount of turbulence occurring is related to this temperature structure.

Inversion

An inversion occurs when the temperature within a layer of air increases with height above the earth. An inversion inhibits the rise and dispersion of pollutants emitted into the atmosphere. Thus, when pollutants are emitted near the ground during an inversion, they remain and cause high concentrations to develop.

Under reverse conditions, when temperature decreases with height, the warmer air near to the ground and the pollutants emitted into it rise and disperse high in the atmosphere. Concentrations of pollutants in the lower layers of the atmosphere are correspondingly lower.

Three different inversion conditions are possible -- radiation, advection and subsidence.

Radiation inversions are the most common. Ground-based, they develop during clear nights when the air cools off faster near the ground than aloft.

During the morning, as radiation from the sun warms up the ground, the air nearest ground warms up first and the inversion gradually breaks down from the lowest levels upward. If a cloud cover moves in prior to sunrise, however, it will continue during the day and high pollution levels will develop.

Advection inversions occur over land areas neighbouring oceans or large lakes such as Lake Ontario. During the spring and early summer the air over the lake's surface is cooled by the comparatively cool water. The air over the ground (especially in developed cities such as Toronto and Hamilton) warms during the day and rises. The warm air is replaced by the cool air from off the lake thus setting up an inversion in the lower layers of the atmosphere.

Advection inversions average about 100 meters in depth. It is very important that very large industrial sources on lakeshore sites have stacks at least 150 meters in height.

Subsidence inversion occur aloft and are caused by the sinking motion of air generally associated with large high pressure areas.

The descending motion results from the lateral spreading of air that occurs outwards from high pressure areas. It causes air to be

compressed thereby increasing its temperature and creating an inversion in a layer of air aloft.

Subsidence inversions become serious due to both the calm or light wind conditions accompanying high pressure areas and the tendency of high pressure areas to remain virtually stationary for long periods of time. An inversion aloft acts as a cap on pollution emissions, preventing them from dispersing into the high atmosphere.

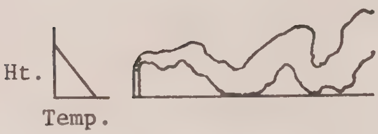
Large subsidence inversions involving thousands of square miles occur over the industrial regions of eastern North America when high pressure areas stagnate there, usually as the western extension of the Azores anticyclone. At these times, high pollutant concentrations occur over urban and valley areas containing large industrial sources of pollution.

Stability

Air stability is determined by the rate at which temperature decreases with height. A neutral condition exists, when temperature decreases at the rate of 5.4 degrees F per 1,000 feet or 1 degree C per 100 metres. When temperature decreases at a greater rate, the air is considered unstable. Light winds and heating from the sun are necessary for this condition to occur. When winds are greater than 6 metres per second, the air will stratify and any instability will tend to break down.

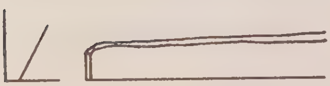
The behaviours of smoke plumes under various stability conditions has been categorized as follows:

1. Looping occurs when the atmosphere is highly unstable (sunny skies and light winds). There is good diffusion. High concentrations may occur for very short time intervals when the plume strikes the ground. Cloudiness and strong winds prevent unstable conditions from forming.



2. Coning occurs when the atmosphere is slightly unstable. Vertical mixing is not as intense as it is when looping occurs. The plume is cone-shaped. Ground level concentrations of pollution from high stacks can be predicted quite accurately. H = effective stack height.

3. Fanning occurs when the atmosphere is very stable (during inversions). There is little vertical motion. The plume meanders horizontally with only slight vertical diffusion. Plume concentrations are high. Ground concentrations vary according to stack height.



4. Lofting occurs when a plume is emitted above an inversion. The plume does not reach the ground but is kept in the unstable air aloft.

5. Trapping occurs when there is an inversion aloft and an unstable layer of air beneath it. The plume is trapped below the inversion layer. High, ground-level pollutant

concentrations accompany this condition. It occurs during persisting periods of high pressure or in advance of an approaching warm front.

Controlling Air Pollution

The maximum concentration of pollution downwind from a source is directly proportional to the emission rate of the pollutant and inversely proportional to the square of the effective stack height. The effective stack height is the height of the centre line of the plume above ground. (See figure 2, Page 8.)

Pollution can thus be controlled by reducing the emission rate or increasing the effective stack height. The former is by far the preferred and most effective method of control. Most particulate matter can be removed through the use of efficient precipitators. Sulphur dioxide emissions can be reduced by burning lower sulphur content fuels.

Effective stack height can be increased by simply increasing the actual height of a chimney. It may also be increased by increasing both exit gas velocity and temperature or by combining the effluent from several sources into one larger diameter stack. These design features cause the plume to rise higher above the stack. Changing these features at times provides the most effective method of controlling an air pollution problem.

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Air Pollution and Human Health

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ironment conservation in Canada

Ministry of the Environment
Hon. J.A.C. Auld, Minister
Everett Biggs, Deputy Minister

Ministry of Health
Hon. R.T. Potter, MD, Minister
S.W. Martin, Deputy Minister

Air Pollution and Human Health

The Problem

Everyone agrees that air pollution is a bad thing - that it should be corrected now and that efforts should be made to prevent it in the future. However, not everyone has the same reason for this concern. Environmentalists worry about the long term effect on the atmosphere; engineers may think in terms of corrosion of buildings and other structures, such as bridges; transportation authorities see pollution as a cause of reduced visibility, both in the air and close to the ground; naturalists may identify air pollution as a threat to the existence of certain animal and plant species.

Despite all these good reasons for controlling air pollution the man in the street tends to think of it primarily as a hazard to health - his own health, that of his children, or that of unborn generations. Ironically, he is less apt to worry about the health of older people - the group who are known to suffer most from unusually high concentrations of pollutants.

The soiling of buildings or corrosion of bridges can be assessed in engineering or economic terms. It is possible to accept the fact that a building must be cleaned every 10 years or that we will budget for a 1/2% wasteage of bridge steel every year. It is much harder to accept this kind of approach where human health is concerned. We cannot say that we will allow "X" per cent of extra deaths this year, rather than spend additional money on pollution controls.

This is the reason why air quality standards are set at such low figures. When we say that the average amount of a substance in the air should not exceed 10 micrograms per cubic metre of air (this could represent as little as one part of the substance per billion parts of air), it is because we hope that this amount, when breathed for 24 hours a day, will not have a harmful effect, on anyone. These standerds are, in fact, an attempt to provide maximum protection for every member of society -- even the weakest and oldest.

Having said this, it must be admitted that it is unlikely that we will ever reach such a state of perfection. Even with the best controls that can be imagined, there will always be some individuals who are peculiarly sensitive to minute amounts of pollutants, and for whom absolute protection is almost impossible.

One aspect of pollution that is very difficult to evaluate is that of personal annoyance or discomfort. For example, a thousand people may be exposed to an odor which is generally acceptable and not ordinarily considered harmful, e.g. that of a bakery. Suppose now that one or two people find this odor so objectionable that it nauseates them and interferes with their enjoyment of life. How many people would agree that the bakery should be closed -- or even made to spend large sums of money in attempting to control the odor?

This simple example underlines the larger philosophical issues of whether any degree of pollution can be tolerated, whether there is ever a level of pollution which causes no significant effect. It also raises the question of how we are to assign values to differing degrees of risk or annoyance.

The "Dose" Concept

As in the case of any drug, the effect of an air pollutant depends partly on the amount to which the exposed person is subjected. It depends, too, on the period of time that the exposure continues. For this reason, it is important to keep in mind the principle of a "time-dose relationship". This phrase describes the fact that effects caused by air pollutants may depend not only on their absolute concentration in the air, but also on the amount of air breathed, the length of time it is breathed and the duration of time since the material was first breathed.

For example, we know that certain miners, when exposed to a given concentration of silica (silicon dioxide), may develop a disease called silicosis, but this only occurs if they have breathed a critical concentration of the material for a certain minimum number of years. It is also known that symptoms of the disease do not appear until a certain additional number of years - with or without additional exposure - have passed.

It has been suggested that another disease, asbestosis, caused by breathing asbestos fibres, may also occur years later in people who, at some time in the past, were exposed to a heavy concentration of that material. This seems to be true in a few instances where people lived close to asbestos mines or processing plants. However, no such effect has been noted in Canada - despite the fact that we are a major supplier of the material. Cases of asbestosis that have been identified in this country have been in people who were occupationally exposed, i.e. asbestos workers.

Concentration of Pollutants

The amount of a substance which exists in a given amount of air is its "concentration". We can describe this in terms of the weight of the substance for a known volume of air (e.g. 10 micrograms of lead in

a cubic metre of air).

In the case of gases or vapors, it is common to speak of volume of the material in a known volume of air, e.g. 1 part of sulphur dioxide (gas) per million parts of air (1 ppm). For sulphur dioxide, for example, 1 ppm would be equivalent to about 2,600 micrograms (millionths of a gram) per cubic metre of air. This is not a constant relationship but one that differs for each substance and depends on its molecular weight as well as on the temperature and pressure of the air.

Permissible Intake

How do we decide what concentration of a given substance can be breathed safely? To arrive at this we should know what amount of the pollutant produces an adverse effect, how much the person may be getting from other sources than air, e.g. in water and food, and how much air is breathed in a given time.

In the case of industrial workers it is common to speak in terms of an 8-hour average, since this is the time most people spend at their work. The amount of a material which it is safe to breathe for this time period is called the "threshold limit value (TLV)". TLV's are calculated for a large number of occupationally-encountered substances. By collecting information about workers who were exposed to excessive amounts, industrial hygienists first learned about the harmful effects of many chemicals. At the same time, they were learning what concentrations could be breathed safely over a man's whole working life.

The average person, during quiet breathing, breathes about 12 to 14 times a minute and takes in 500 cubic centimetres (cc) - about 1 pint - of air with each breath. If we take the higher figure of 14, then we can see that the average person takes in about 500 x 14 x 60 (min.) x 24 (hours) = 10,080,000 cc of air in 24 hours. This is approximately 10 cubic metres of air.

A man doing fairly strenuous work may breathe 20 times a minute and take in as much as 1,000 cc of air with each breath, so that his intake in an 8-hour working day would be 1,000 x 20 x 60 x 8 = 9,600,000 cc, which is again about 10 cubic metres of air.

If we assume that the air in the working environment contains some pollutant at a concentration of 2 milligrams per cubic metre of air, then the workman could take in up to 20 milligrams (10 x 2) of that substance during his 8-hour working day. Of course, it is unlikely that it would all remain in his lungs, since some is bound to be expired again. In this particular case, if we decided that an intake of 20 milligrams per day was a "safe" dose - one that has no adverse health effect, - then the TLV for that substance would be set at or below 2 milligrams per cubic metre of air (usually abbreviated as 2 mg/m^3).

We must also make allowance for the amount which will be breathed during hours away from work, when the workman will breathe about another 6 cubic metres of air. This will be air in which, presumably, the contaminant will be at a much lower concentration than in the working atmosphere. Suppose it were at one-tenth the concentration, i.e. 0.2 mg/m^3. His "off-work" exposure would then add about $6 \times 0.2 = 1.2$ milligrams to the 20 mg which he received while at work.

Whether this additional amount is to be considered significant will depend on how the particular substance is handled in the body. If it is something which is fully retained and builds up to a toxic level, it could be of some importance. On the other hand, if it is something that is rapidly detoxified or excreted from the body, it might be less important.

In the case of some pollutants there may be an additional contribution from other sources, e.g. food and water, chemicals handled in pursuing a hobby, household and garden pesticides, and so on. The fate of these in the body must also be considered. To mention lead again - for most people the amount consumed in food and water is 6 to 10 times as much as they breathe. However, of that which goes into the digestive system very little is absorbed, while much more of that which is breathed is retained in the body. This results in almost equal amounts being absorbed from the lungs and from the digestive system, although the amounts entering the two systems are quite different.

All of these factors must be considered in establishing safe levels, either for occupationally exposed workers or for the general population. Obviously, the level of exposure which we permit for the public will be less than that which the healthy industrial worker can tolerate.

Relationship Between TLV's and Community Air Quality Objectives

Although community air quality objectives will always be considerably lower, we cannot apply any constant factor to this relationship. A comparison of air quality objectives and TLV's in Ontario would reveal that the safety factor applied may be 2, 5, 10, or even 100 times, depending upon the substance in question.

A good example is that of sulphur dioxide (SO_2). The TLV which we use in industry is 5 parts of SO2 per million parts of air. At the community level, however, we require the 24-hour average to be at or below 0.1 ppm, i.e. 1/50th of the industrial level. This is a very low level of SO_2 to be concerned about, but the figure was chosen because some early studies suggested that the health of vulnerable people might be affected if a higher level were maintained for a prolonged period of time. There is now some question whether such a low concentration of SO_2 could have any harmful effect but until this is fully resolved most authorities will retain the low figure.

Mixed Pollutants

This brings us to another consideration - that of mixtures of pollutants. Studies or experiments with SO_2 alone have not shown any effect on health at 1.0 ppm (10 times our community standard) or even at somewhat higher concentrations. However, in situations where SO_2 was one of a mixture of pollutants - including very small "respirable particles" - there is some evidence that levels somewhere between 0.1 and 1.0 ppm could have some harmful effect on susceptible people over a long period of time.

The effect that has been most commonly reported is that people with chronic bronchitis tend to have an increase in their symptoms - cough, sputum production and shortness of breath. It must be emphasized that this has been noticed when the SO_2 content of the air was increased but is not necessarily due to SO_2. SO_2 is produced whenever fossil fuels - particularly coal and oil - are burned. The production of this gas is bound to increase in cold weather, and there is always the possibility that the cold air itself or some other pollutants are the main culprits.

What Kind of Health Effect?

Air pollution implies the introduction of harmful material into the body, either by direct contact - as with the skin - or through the respiratory system. We can also think of air pollution as affecting food and water, which may then be taken into the body by mouth.

Some of the effects which have been ascribed to air pollution are listed below (Appendix 11 lists some common air pollutants and their presumed effects):

(a) Damage to the lungs and other parts of the respiratory system

Experimentally, a number of common air pollutants are damaging to lung tissue or interfere with lung function in other ways. To produce these effects, however, it is usually necessary to employ concentrations of the substance much greater than are ever encountered in community air. This has given rise to speculation that mixtures of pollutants, as they occur in community air, may have a combined effect greater than that expected from individual types.

This seems to be particularly true for some gases, like sulphur dioxide, which seem to be much more harmful in the presence of moisture and fine particles than in their pure state.

In theory the fine particles adsorb the gas and then carry it down into contact with the lung tissue. This is the explanation given for the severe effect of air pollution "episodes", when disease and death result from concentrations of pollutants which, individually, would not be considered harmful.

An air pollution episode is defined as a period, usually of several days duration, during which stagnating air causes an accumulation of pollutants close to the earth's surface, where it can be breathed. In the past, such episodes have always occurred in association with cold, damp air, and at times of maximum fuel consumption for heating purposes.

The effect on lungs is not specific for this condition. People with advanced heart or lung disease are particularly susceptible. The result may be an aggravation of their existing condition, often leading to death.

This dramatic effect of major pollution episodes naturally leads to speculation about the damage which may result from breathing lesser concentrations of polluted air over many years. This is discussed below.

(b) Acute intoxication by poisonous substances

This is a rare event, but can follow an accident such as a wrecked railway tank car which releases dangerous amounts of ammonia, chlorine, nitric acid, or some other toxic material.

(c) Chronic intoxication resulting from the inhalation of small amounts of a toxic substance over a long period of time

This is most likely to occur in "occupational" exposures, and it is from the experience of industrial workers that most of our early information came. Now we are concerned about how much effect there could be on the public, i.e. people living in the vicinity of a plant which discharges toxic substances to the atmosphere.

The emission of lead from gasoline engine exhaust is another case in point. Lead tends to accumulate in the body. If a sufficient amount is retained, it may cause lead poisoning - a serious disease of the nervous system. Actually, the dose of lead acquired in this way is usually well below that required to produce any kind of symptoms. This is one reason why there is still lack of agreement on removal of lead from gasoline. The decision would be easier, were it not for the fact that removing lead may cause an increase in other exhaust gases.

(d) Allergic reaction to materials in the air

Plant pollens, such as ragweed, constitute the commonest form of air pollution which produces a recognizable effect, i.e. hay fever. Some chemical substances can also act as allergens or as substances which enhance the body's reaction to allergens. This is an area in which there is still much to learn. A few physicians believe that allergy is a common response to industrial chemicals, while most consider this an unusual cause.

(e) "Irritation" of eyes, nose, throat or skin

This is a common complaint when people are exposed to "photochemical smog" which results from the action of sunlight on automotive exhaust gases. The main products are compounds known as oxidants and aldehydes which can make the eyes water, make the throat feel sore and dry, and cause itchiness of the skin. This kind of smog is more common in southern cities, notably Los Angeles, but may also occur elsewhere with high concentrations of automotive exhaust gas and bright sunshine.

(f) Cancer

The mode of action of carcinogens (cancer-causing substances) is not yet fully understood, though more is being learned each year. We know that certain products of combustion, called polycyclic hydrocarbons, can produce cancer in test animals in the laboratory. Whether the minute amount of these chemicals that we breathe can have a similar effect on people is not fully established.

There is little hope of completely ridding city air of these substances so long as we burn coal, oil and other fossil fuels. Some people believe that these substances are responsible for the fact that lung cancer is more common in cities than in rural areas.

Similar substances also occur in cigarette smoke, and lung cancer is essentially a disease of cigarette smokers, occurring only rarely in non-smokers. If the polycyclic hydrocarbons are the cause of this disease, it is not difficult to see why smokers should be affected, as their form of "personal air pollution" is the most intensive form of pollution that can be experienced on a long term basis.

(g) Nuisance Effects

Many chemical substances have unpleasant odors at concentrations far below those at which a toxic effect could occur. These odors may give rise not only to annoyance but, in some cases, to severe psychological disturbance in those who are most offended by them.

A similar effect may be produced by some dusts. While some are intrinsically harmful, there are others which are biologically inert but which can be very annoying because of their soiling effect on materials, automobiles, laundry, etc.

(h) Noise Damage

Noise has been described as unwanted sound. This is gradually coming to be accepted as a form of air pollution. It has both physical and psychological effects, ranging from loss of hearing, to sleep deprivation and general irritation. Some places have had anti-noise laws for years but, in most cases, they have been difficult to enforce because of imprecise methods of measuring and assessing the effect.

Better methods of regulating this hazard are gradually being formulated.

In summary, pollutants may be classed as systemic (general) poisons, pulmonary or other irritants, allergens, carcinogens, odors, or physical agents (such as noise). There is great variability in the degree of damage that they may cause. The object of a control program should be to identify those agents which cause appreciable harm and to concentrate first on regulating the ones which pose the greatest threat.

Research Methods

How do we study the effects of air pollution?

If it were possible to give a person a certain "dose" of air pollution and then record his reaction to it, it might be easier to say what the effects on human health can be. In practice, this is true of only a very few pollutants, because most occur in community air in doses or concentrations too small to give an immediate, observable effect.

In fact, the result that we are mainly concerned with is that from breathing polluted air for a prolonged period (10 years? 20 years?). The obvious difficulty is, not only that we have to wait 10 or 20 years to see the results but, when we do that, we then have only a very inexact idea of what the person has breathed in the interval.

However, there are a number of more helpful methods by which we can study the effects of air pollutants, such as

(a) observing the effects on people who are regularly exposed to known pollutants in their occupation

This can give very good information about how the pollutant affects the body but here, too, the concentration is usually many times higher inside the plant than outside in the community air. It is not necessarily true that a small amount of something breathed over a long period of time will have the same effect as a large amount over a short period of time.

(b) studying the effects of major air pollution "episodes"

There have been a few episodes in the past - mainly in London and New York - when heavy "smog" (smoke and fog) persisted for several days combined with low temperatures and absence of air movement. During such episodes many people died - undoubtedly as a result of the smog.

Those who succumbed were almost all very old or people with chronic disease of lungs or circulatory system. Some small premature babies were also victims.

Unfortunately, these episodes have mostly been studied in retrospect and the exact nature of the pollution was not known. It can be assumed that it was basically similar to the usual pollution of the cities affected though at greatly increased levels, but even this information is not too helpful in teaching us about long-term effects of ordinary day-to-day pollution.

(c) laboratory experiments

Research workers have exposed small animals, monkeys, and even human volunteers to measured amounts of pollutants in an attempt to determine their effect. As mentioned earlier, the amount of a substance which will produce an effect in the laboratory is usually large in comparison with the amount in community air.

The kind of effects noted are symptoms - such as cough, pain, shortness of breath - or objective changes such as damage to tissue cells, decrease in respiratory function, or changes in the biochemistry of the blood. Animal studies add to our knowledge of how pollutants work, but the findings cannot be directly translated to humans. The studies on humans can, of course, only give information on short-term effects.

(d) epidemiological studies

Our best information about the long-term health effects of air pollution comes from comparisons between communities or groups of people, or of the same group under different conditions. For such a comparison to be valid, the two groups must be as similar as possible with respect to sex and age distribution, economic status, smoking habits, and any other factors which might influence the findings.

In practice, because the effects are usually difficult to measure, the larger the number of people studied, the more reliable the conclusions are likely to be.

Another way of getting information is to select a group of people who have a condition which is liable to be affected by air pollution - such as asthma or bronchitis - and to observe their reaction to changes in the pollution level of their environment.

Usually such people are requested to keep a diary in which they record "attacks" or increases in their usual symptoms. This information is then collected and compared with known changes in the levels of various pollutants. At the same time, it is important to note meteorological conditions as some symptoms may change in response to temperature, humidity, barometric pressure, or wind strength.

All in all, useful studies are obviously very difficult to achieve. Medical literature contains hundreds of articles on the health effects of air pollution, but only a handful of these really add to our knowledge of the subject.

An example of a useful study is one which was carried out by some English workers who studied 5,000 children born in different communities in the same year. The communities were classified according to the average amount of sulphur dioxide in the atmosphere. The children were observed for fifteen years to determine whether differences in respiratory disease rates could be recognized. Some valuable points were established, but even so thorough a study as this ran into difficulties. During the lengthy period of study changes occurred in fuel usage, and this affected sulphur dioxide (SO_2) levels. New methods of measuring SO_2 came into use and the reliability of the old method was questioned.

Nevertheless, some valuable information was obtained. It was found that increased exposure to polluted air, as indicated by SO_2 concentration, was associated with increased incidence of lower respiratory disease - chiefly pneumonia and bronchitis. The effect was much more marked in families of low socio-economic status. Bronchitis in children is fairly common in Britain, in contrast to Canada where it is relatively unusual.

What Diseases are Caused by Air Pollution?

This is the question we would most like to be able to answer definitively. For the present we can only say that certain occupational diseases, such as silicosis and asbestosis, are quite clearly related to the inhalation of toxic substances, and that a large proportion of chronic respiratory disease and lung cancer can be blamed on cigarette smoking. Polluted community air seems to play an enhancing effect in these latter conditions but, to date, this is very difficult to quantify.

We can say that chronic bronchitis, lung cancer and some forms of emphysema are considerably more common in city dwellers than in people who live in the country. There is a great temptation to take this as evidence that air pollution is the cause, but there are a number of reasons why we should be cautious about this conclusion.

One of them is that the above-mentioned difference between urban and rural populations is much less noticeable in females than in males. Another point is that, although these diseases remain more common in the cities, the rate of increase is just as obvious among country people. It could be argued that this means that pollution is extending into the country, but this is not borne out by atmospheric surveys. In fact, even in the cities many of the pollutants which are regularly monitored have been decreasing in recent years.

Another problem is that most of our information about the prevalence of diseases is derived from mortality (death statistics), rather than from any exact knowledge of the occurrence of diseases. The reason for this is that a "cause of death" must be recorded on every death certificate while there is no comparable record of sickness.

Estimates of the prevalence of a disease are just that - estimates. The fact that a particular doctor or hospital encounters a certain amount of a given disease is not an accurate indication of how common it is in the population. Some diseases rarely cause death, so they may really be more common in the community than the death records indicate. Other diseases, such as heart failure and pneumonia are common causes of death and so may be unduly emphasized in mortality figures.

These are some of the difficulties one encounters in trying to establish the effects of air pollution.

Conclusions

1. There is no doubt that people with chronic respiratory diseases are adversely affected by some kinds of air pollution.

2. Some respiratory diseases are caused by the more intense forms of air pollution - tobacco smoking and occupational exposures.

3. Community air pollution may be the cause of some respiratory diseases. There is also a possibility that the inhalation of trace amounts of metals and other chemicals from the air may contribute to other chronic and degenerative diseases, which are generally on the increase.

What about the future?

The foregoing description of what is known about the effects of air pollution on health is a very "middle of the road" approach. Some medical authors have gone so far as to imply that half of all human illness can be attributed to air pollution. Others, just as well-qualified, say that there is no evidence that air pollution causes any illness.

It is apparent that much more information is needed before a consensus can be reached.

Obviously, one cannot wait for clear proof of harmful effects before deciding to curtail air pollution. The most logical approach is to restrict contamination of the air by substances which are known to be harmful in other contexts, i.e. in occupational exposure or laboratory experiments.

Some of the problems inherent in studying the effects of air pollution have been mentioned. It appears that the best information comes from statistical studies which in turn depend on good medical records. Some comprehensive health insurance schemes now maintain life-long health records of individuals and it may be from such sources that further knowledge will come. Records which are kept for "medicare" programs are also becoming increasingly valuable for statistical purposes.

In general, epidemiologists believe that careful long term studies will eventually reveal the more subtle ways in which our health and longevity are affected, not only by air pollution, but by other environmental factors as well.

This is the best justification we have for demanding good environmental management now - to protect us against those adverse effects which may not yet be fully appreciated.

In Ontario, we are fortunate in having an efficient and rapidly developing air management system. In the few years since the province took over this function, great progress has been made both in identifying sources of pollution and in beginning to bring them under control. Obviously, there is no room for complacency about this situation -- too much remains still to be done -- but, with the progress that has already been made, we are justified in looking to the future with optimism.

APPENDIX I

GLOSSARY

1) *Air Pollution* - the presence in the air of any substance or mixture of substances in such concentration that they may have a harmful effect on people, animals, vegetation or structures.

2) *Ambient Air* - the surrounding air, that which we breathe.

3) *Micron* - a unit of measurement, one-thousandth of a millimetre or about a twenty-five thousandth of an inch.

4) *Occupational Disease* - a disease which characteristically occurs in workers with a particular occupation or in a particular industry.

5) *ppm* - parts per million

APPENDIX II

EFFECTS OF INDIVIDUAL POLLUTANTS

Carbon Monoxide (CO)

This is a toxic gas which is produced when carbon-containing materials are burned in an oxygen-deficient environment. (When there is ample oxygen, the relatively harmless carbon dioxide is produced.) Carbon monoxide acts by attaching itself to the hemoglobin in the blood and interfering with the collection and distribution of oxygen.

The amount of CO in the blood depends not only on how much there is in the air, but also on how long the person breathes it and how active he is at the time (as this affects breathing rate and depth). An amount that would not bother a sedentary person could cause headache and dizziness in a hardworking man in one hour.

While the poisonous effect of high concentrations (e.g.500 ppm or more) has been known for years, there is still no agreement on whether prolonged exposure to low levels may also cause ill health. The concentration on city streets may vary from 1 to 50 parts per million (occasionally even higher) depending on the amount of automotive traffic.

Even in the absence of recognizable long-term health effects, some researchers have demonstrated short-term effects on vision, hearing and mental ability at relatively low concentrations of CO.

People who smoke cigarettes expose themselves to CO concentrations far higher than those on a busy street. Smoking and vehicle exhaust are additive factors in CO exposure. The elimination or reduction of both these sources is highly desirable for human health.

Hydrocarbons and other organic chemical compounds

At any given time the air contains a large variety of organic compounds of various degrees of complexity. These are derived from industry, transportation and heating sources and even from natural causes such as decaying vegetation. Some of them have known physiological effects on man, animals or plants, including the ability to produce cancer in certain laboratory animals. Others are identified but their effects are not known.

Some physicians believe that these chemicals can make man more susceptible to certain allergic substances. Some think that the excess deaths from respiratory diseases (including lung cancer), which occur in cities, must be caused by them. On the other hand, many of these compounds are less common now than when coal was more widely used as a fuel. The real reason for the continuing increase in respiratory disease - other than that portion resulting from cigarette smoking - is not known.

Oxides of Nitrogen

Nitrogen makes up about 80% of the air around us. When anything burns at high temperature there is a good chance that some nitrogen will combine with oxygen in one of a number of possible proportions. The most common compound of this group is nitrogen dioxide (NO_2). Like SO_2, it can act as a pulmonary irritant at higher concentrations and may possibly do so at the low concentrations at which it occurs in community air.

In southern latitudes, NO_2 may react with hydrocarbons (e.g. from fossil fuels) under the influence of ultraviolet radiation, to produce the irritating aldehydes and oxidants which are characteristic of photochemical smog.

Particulate Matter

By convention, this term is restricted to solid or liquid particles which are small enough to remain suspended in the air. The tendency of a particle to settle out of the air is largely a function of its size. For the most part, only particles under 40 microns in diameter remain suspended and can be breathed in. The normal filtration system of the human respiratory system (hairs, air passages, mucus) remove most particles over 5 microns in diameter. Only those below this size get into the lungs.

These particles may be retained or exhaled again. Those which are retained may be quite inactive, may exert a local irritant effect, or may be dissolved and absorbed into the blood stream and carried to other parts of the body.

Many people believe that gases like SO_2 and nitrogen dioxide are more likely to be carried deep into the lung recesses if they are first adsorbed onto some sort of particulate matter. This may explain why the expected effects of polluted air are often not achieved during laboratory experiments when pure gases are tested. Remember that "particulate matter" is a very non-specific term, unless one knows the composition and size of the particles.

Sulphur Dioxide (SO_2)

When a sulphur-containing fuel such as coal or oil is burned, one of

the end products is sulphur dioxide gas. As a result, this material can be identified in the ambient air of most communities. In the neighbourhood of smelters where sulphur-containing ores are roasted, the concentration of SO_2 can be quite high at times. SO_2 also occurs in discharge gases from incinerators, some pulp plants, and a number of other industries.

In the air, SO_2 can be converted to sulphuric acid or to its salts (sulphates). Because these compounds are commonly found in polluted air, and because they are relatively easy to measure, it is not unusual for people to equate the effect of polluted air with its SO_2 content.

Many studies of the health effects of polluted air refer to the SO_2 content of the air, but in most cases the authors state that SO_2 should be taken only as an "index" of pollution rather than as being responsible for the effects. In Ontario, the pollution index published for several cities is based on two constituents of polluted air - SO_2 and particulate matter. When the concentration of these two increases, one can assume that other pollutants are also increasing and/or that the weather conditions which usually disperse pollution are inoperative.

In experiments with laboratory animals it requires concentrations of SO_2 considerably higher than those encountered in ambient air to produce effects. A partial explanation is contained in the note on "particulate matter".

Trace Substances

Many chemical elements find their way into the air, either by a natural process or as a result of man's activities. The term "trace substance" indicates that they usually occur in very low concentrations.

Some have been of particular concern - cadmium, fluorine, lead and mercury. There are many others, any one of which may claim attention in the future. Other substances, such as asbestos and silica, are also of concern because they are infamous as causes of occupational disease. At various times it has been suggested that some of these - particularly asbestos, fluorine and lead - could pose a community as well as an occupational hazard. Recent reviews suggest that, at least for the present, neither asbestos nor fluorine is a problem in this sense.

The significance of lead as a potential community problem remains somewhat undecided. The amount of lead in the air may not in itself be too serious, but much of it settles on the ground and, in certain circumstances, gets into the food chain. At present, indications are that a problem could develop in the future, and that attempts should be made to reduce the amount of lead being added to the environment.

This may eventually lead to a decision to ban the use of tetra-ethyl lead in gasoline, although there is the problem that many of the cars now on the road require premium or high octane fuel.

To continue giving satisfactory performance on unleaded gasoline, such cars require the addition of aromatic hydrocarbons to the fuel, and such additions may increase hydrocarbon emissions from the tail pipe.

APPENDIX III

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These are only a few of hundreds of reference works on this subject. Interested students will find many sources of information in school or university libraries, or in those of the appropriate government departments.

APPENDIX IV

STATISTICAL INFORMATION

The accompanying graphs are intended to give some idea of the changes which are occurring in deaths from lung cancer and chronic respiratory disease, and at the same time to point out some of the pitfalls of statistical interpretation.

All statistics are imperfect and graphs can be manipulated to give unreliable information.

The graphs shown here could be considerably changed in appearance and in the effect they convey by making them wider or narrower, i.e. by using a different scale or a different overall size. For example, the graphs for males and females are on a different scale-- the "rate" numbers along the sides indicate it is. The reason for this is that the number of males dying of lung cancer and chronic respiratory disease is several times that of females. If put on the same scale, the female lines would be so close together as to make reading difficult.

The graphs deal with two internationally accepted categories of disease.

'Respiratory cancer' if officially 'cancer of trachea, bronchus and lung'. As the vast majority of these are cancer of the lung, the graphs can quite properly be considered to show what is happening to lung cancer in Ontario. Since most people with lung cancer die of their disease, these figures also reflect the "prevalence" of lung cancer.

'Chronic respiratory disease' refers essentially to two official categories: 'Chronic bronchitis, emphysema and asthma' and 'other respiratory disease' - the group that is left when all easily classifiable diagnoses are removed.

The three lines represent:

————————	Ontario - average experience for the whole province.
-·-·-·-·-·-·-	Cities - a composite rate for the metropolitan areas of Hamilton, London, Ottawa, Toronto and Windsor.
··················	Rural - a composite rate for the rural component of several counties.

Immediately we see the possibility of 'author's influence' on the statistics, as there is no assurance that the selected groups are fully characteristic of all city vs. all country dwellers.

Also, the rates are based on the portion of the population 'aged 35 and over'. This is probably quite valid for 'respiratory cancer', as very few people die of these diseases below the age of 35. However, the case of 'chronic respiratory diseases' is somewhat different, since here as well all the deaths which occurred in the province in this category of diseases have been charged against the portion of the population aged 35 and over. This has been done for convenience, but if we were to separate out those who died under age 35 the rates for chronic respiratory disease would be somewhat less than those shown in these graphs.

Next, we come to the question of interpretation. Ideally, the reader should have the actual figures (the 'raw' data) and should be allowed to make his own deductions.

The graphs are meant to summarize the information but, as cautioned above, could also be used to influence the reader in his interpretation.

A few reliable observations can be made:

a) In males, many more die from lung cancer than from chronic respiratory disease, and this is true even in the country.

b) In females there is also a difference, but it is much less obvious.

c) In both of these disease categories the number of male deaths is much higher than among females.

d) Generally, the death rates in cities from these diseases are higher than the provincial averages. The country rates are usually below the provincial rate. This is very obvious in the male cancer graph, less so in the others.

e) All of these diseases are on the increase.

f) The rate of increase (as represented by the angle of the graph) is about the same in the country as in the city, although the city rates remain higher.

Other deductions can be made from these graphs. It is left to the reader to decide whether or not this information is consistent with the theory that air pollution contributes to these diseases.

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Death Rates per 100,000 in Ontario residents, aged 35 and over from Respiratory Cancer and Chronic Respiratory Disease, in the years 1960-69.

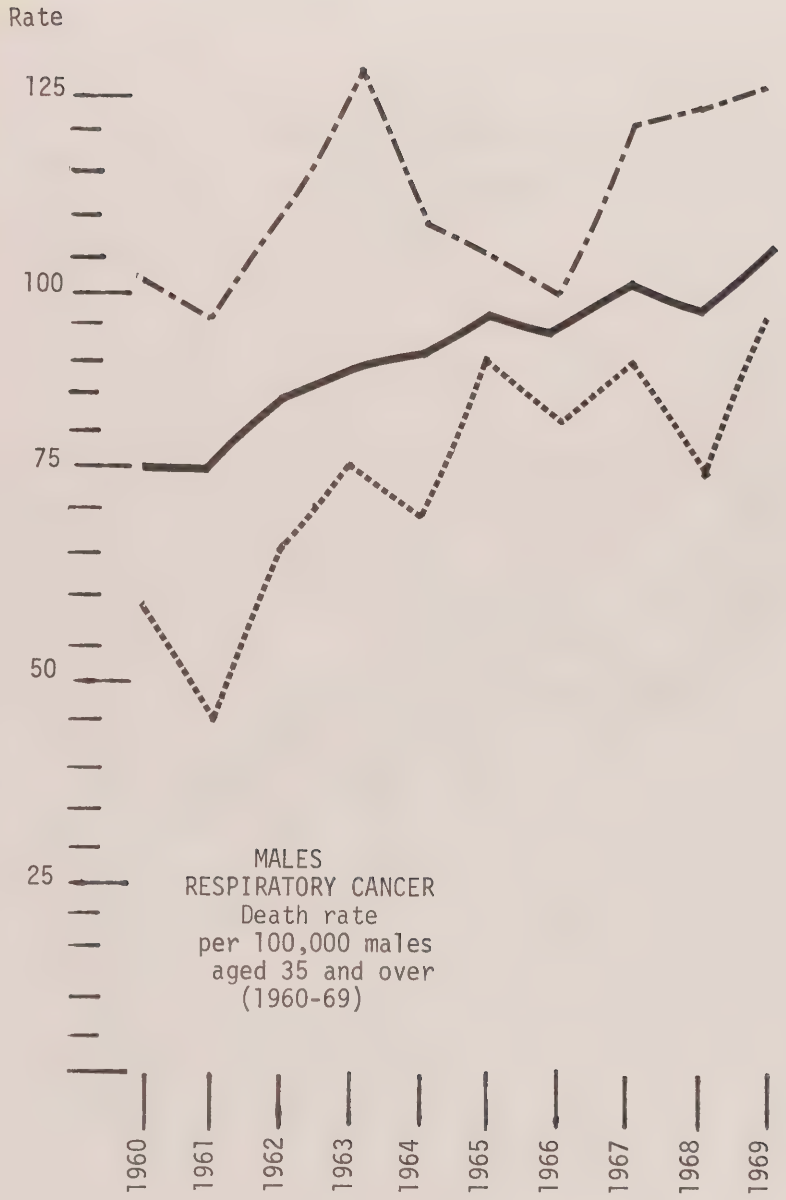
RESPIRATORY CANCER				CHRONIC RESPIRATORY DISEASE		

- MALES -

ONTARIO	CITIES	RURAL		ONTARIO	CITIES	RURAL
75	102	58	1960	41	52	38
75	96	45	1961	41	43	25
84	111	66	1962	44	45	39
87	132	76	1963	51	57	57
89	111	68	1964	50	55	51
97	104	90	1965	62	67	69
92	96	82	1966	62	65	66
102	122	91	1967	63	64	80
99	123	74	1968	67	69	65
108	125	95	1969	73	72	74

- FEMALES -

ONTARIO	CITIES	RURAL		ONTARIO	CITIES	RURAL
8	10	5	1960	12	13	11
10	12	7	1961	12	12	9
12	14	10	1962	14	13	12
11	14	3	1963	13	10	22
12	15	20	1964	11	10	18
15	18	8	1965	15	14	12
14	16	6	1966	15	13	11
14	16	14	1967	14	16	14
15	18	15	1968	15	14	13
18	21	24	1969	19	18	18



Rate
125
100
75
50
25
1960
1961
1962
1963
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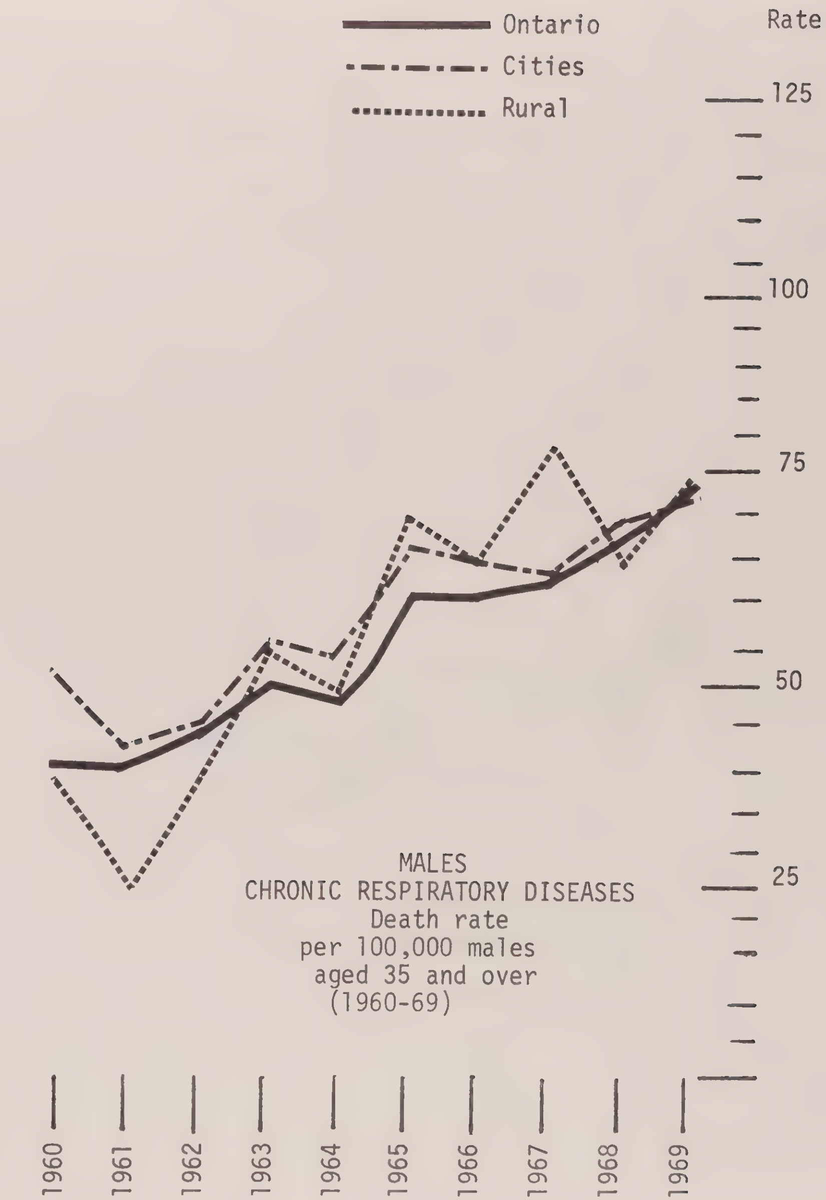
1968
1969
MALES
RESPIRATORY CANCER
Death rate
per 100,000 males
aged 35 and over
(1960-69)



Ontario
Cities
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1960
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FEMALES
RESPIRATORY CANCER
Death rate
per 100,000 females
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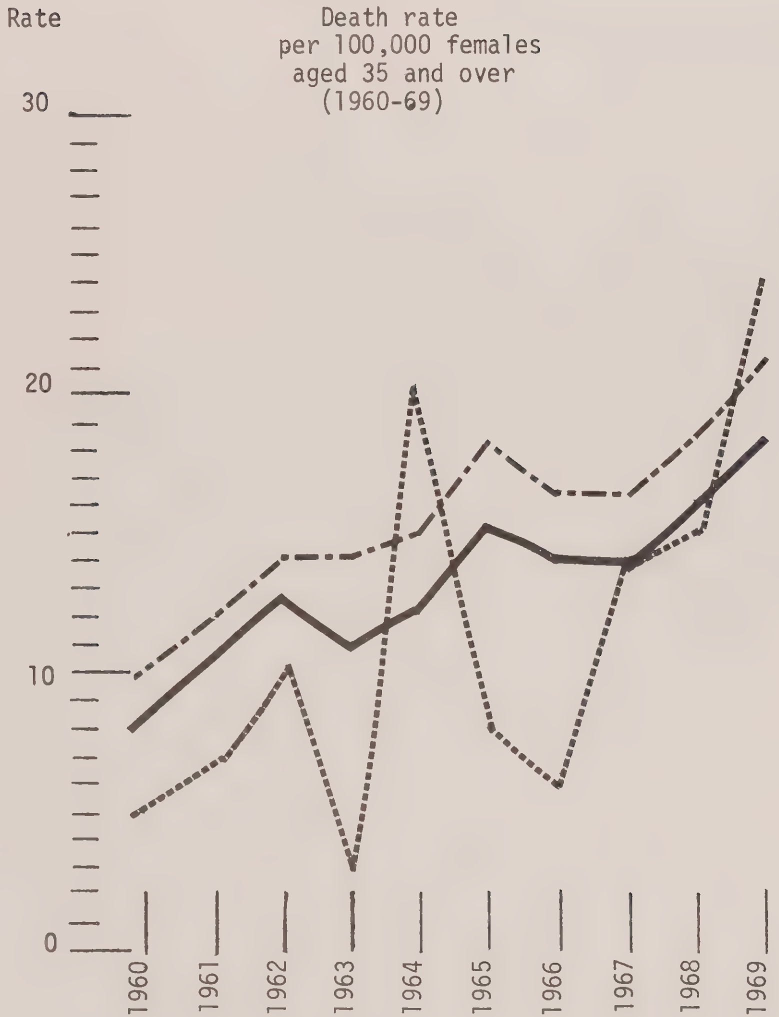
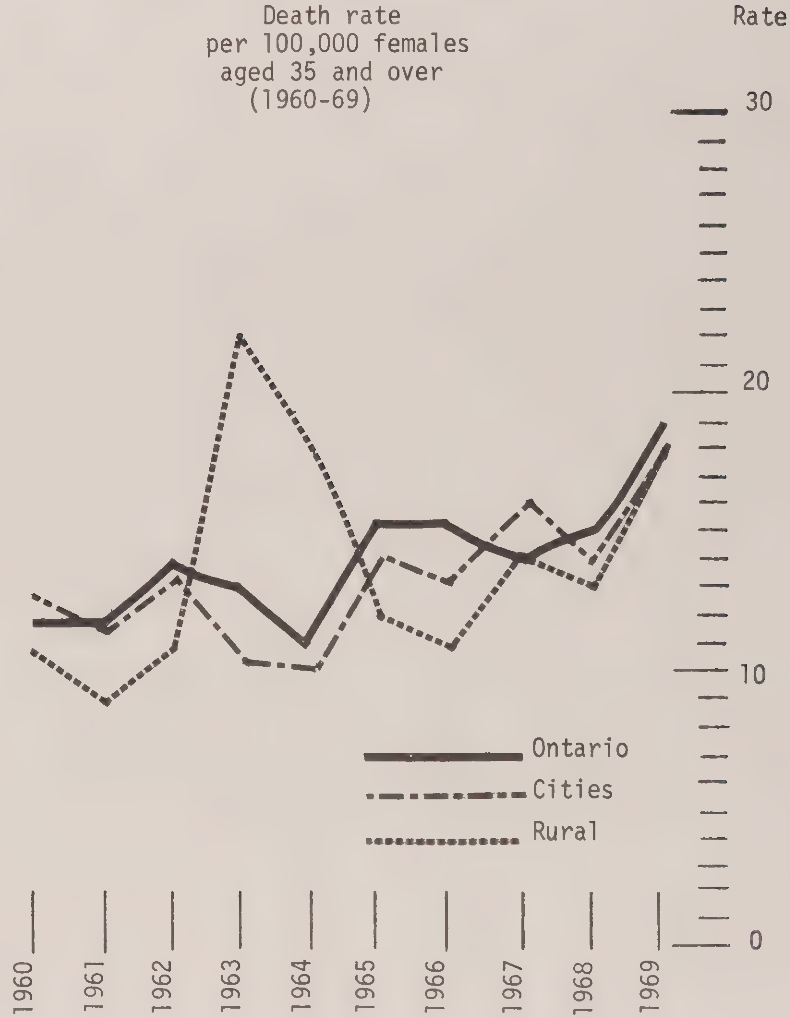


FEMALES
CHRONIC RESPIRATORY DISEASES
Death rate
per 100,000 females
aged 35 and over
(1960-69)



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of the
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Wood Duck Management

ONTARIO
PROVINCE OF OPPORTUNITY

Department of the Environment
Hon. George A. Kerr, Q.C., Minister J.C. Thatcher, Deputy Minister

C O N T E N T S

WOOD DUCK

MANAGEMENT MANUAL

Introduction

From a continent-wide view, wood ducks once were regarded as a vanishing resource. We've come a long way since those times and, thanks to proper management in many areas of the eastern United States, "woodie" populations have grown and once more these birds are a common sight. The reason for their original decline was tied to a lack of natural tree nesting cavities after the mature eastern forests were cut over. Artificial boxes came into vogue as replacements for the hollow trees, but they were expected to work miracles beyond their worth. Often boxes were placed in areas which to the human looked like good duck habitat. Perhaps it was for mallards - but not for woodies. Naturally, wood ducks were not attracted.

It is the purpose of this management paper to offer up-to-date information on wood duck nesting structure designs with emphasis also on the final location of these structures. It is also the intention of this manual to set guidelines for the creation of wood duck habitat which can be incorporated easily into low-quality swamp timber areas which are common throughout southern Ontario.

Breeding Habitat

On natural sites, temporarily flooded bottomland hardwoods no doubt produce the most wood ducks in Ontario. Northern hardwood species such as oak, maple, cottonwood, ash and elm are prominent in most areas. Farther south in Ontario, swamps consisting of red maple, silver maple, elm and sycamore associations are found less commonly.

Cover Requirements

Psychological and physiological security is afforded to breeding pairs by cover that is close overhead and around the ducks, but allows free swimming. About a 50:50 ratio of open water and cover will suffice. The best cover is trees, shrubs, or both. The optimum stage of tree growth is young reproduction, which furnishes low over-head and lateral cover.

There are many shrubs that provide good cover, especially when they are mature. The most desirable is button bush *(Cephalanthus occidentalis L.)*, but alder and willow afford good cover over streams. Less valuable, but still acceptable shrubs are blackberry, greenbrier, sweet pepperbush, sweetbells, viburnum, winter berry, swamp privet, leather leaf, dog-woods, sweet-gale and prickly-ash.

Form, spacing, shape, height and durability of shrubs determine their value to wood ducks. Mature shrubs are best. The ideal shape includes a strong, durable stem that rises about 2 feet above the water and spreads into dense, overhanging branches with room beneath the crown for ducks to swim freely.

Areas where shrubs do not exist contain certain emergents which

seem to fulfill wood duck requirements. They include cattail, soft rush *(Juncus)*, bulrushes *(Scirpus)*, burreed and phragmites.

Loafing sites in the form of logs, stumps, muskrat houses, islands or scattered shoreline are extremely important for breeding pairs.

Water Requirements

Woodlands must be flooded at the time the birds are seeking nest sites. For an area attractive to wood ducks, water depth should be between 3 and 18 inches. Because woodies prefer still or slow-moving water sheltered from the wind, flooded woodlands are especially attractive. A guideline maximum flow for streams is about 3 mph, if an abundance of back-waters and slack eddies are present.

Water should be present in Ontario from the middle of April until the middle of September, with the critical periods occurring between May 15, and August 1. Water should be available during the incubation period, but if water is present within at least one half-mile at that time for the last half of the incubation, the loss of temporarily flooded areas is not critical.

Nest Requirements

Over much of the wood duck's breeding range nest cavities are a limiting factor. If natural cavities are the only nest sites, 20 acres of nesting habitat to 1 acre of brood habitat is ideal. However, in the interest of positive management natural cavities should be regarded as being supplemental only, and every effort to erect artificial structures should be encouraged.

Natural cavities over water are most acceptable, therefore this is the natural location to duplicate with artificial structures. If the

forest is relatively open, wood ducks will seek nests up to one half mile from water, but locating boxes farther than this from water is not wise.

Brood Rearing Habitat

Many of the requirements for brood habitat differ from habitat that attracts nesting pairs. There are five main differences:

1. Animal foods are of increased importance
2. Water must persist until the young can fly
3. Dense cover is of greater importance
4. Herbaceous emergents are of increased importance
5. Trees are not necessary

There is probably no upper limit to the size of an area that will support a maximum brood density of optimum proportions if distribution of water, cover, food, and loafing sites are present. Although a minimum size has not been clearly established, it does not appear worth considering areas of less than 10 acres in size. If water areas are separated by more than 50 yards of land, they are considered isolated. In stream habitat, small brood units, each less than 10 acres in area, should be within a quarter of a mile from each other.

The more shoreline per acre of water the better, provided the distance between opposite shores is not less than 100 feet. This width is necessary to keep predators from trapping broods in cul-de-sacs.

If the requirements discussed in this section are fulfilled, it should be possible to produce two to five flying young per acre each year.

Food Requirements

Animal foods are of critical importance to newly hatched and young ducklings, particularly suface-swimming and flying insects.

Duckweeds *(Lemna and Wolffia)* are important not only for plant foods, but also for the insect life they harbor. Research indicates that insect life is most important until the duckling reaches four weeks of age, then plant foods increase in importance.

Cover Requirements

Overhead cover within a foot or two of the water is vital for wood duck broods. Shrubs alone provide this requirement which living trees cannot do. Tangles of living, dead and dying trees in shallow water up to 3 feet also provide excellent cover. This is especially true for broods that hatch before leaf cover has appeared. The best cover, especially buttonbush, grows as densely together as possible, and allows broods to swim freely under the crowns. Ideal cover composition for broods is

40 - 70% herbaceous emergents

30 - 50% shrubs

0 - 10% trees

Optimum brood habitat should be 75% cover and 25% open water, with a minimum of one-third cover to two-thirds open water.

Emergent plants are much more important for broods than breeding pairs. Although shrubs are desirable for brood cover, emergents that perform the same function are important, and brood use may be high in areas containing little or no shrub habitat.

Water Requirements

Water depths affect the relations between quality, variety, and distribution of food and cover. Generally all wood duck needs are fulfilled by depths between shoreline and 6 feet. The 3 to 6 foot depth

provides the open water unit. Optimum distribution of water depths in brood habitat is estimated as follows:

0 - 1 foot, 25% of the area

1 - 3 feet, 50% of the area

3 - 6 feet, 25% of the area

Openings and channels 5 to 20 feet in width should be scattered rather evenly throughout the cover.

Highest brood use is in habitat with quiet water. On streams this is where water moves less than 1 mph. Broods seldom use faster water, except to get from one use area to another.

Suitable water must be available until the young are on the wing. In Ontario, this means that water must be available until the middle of September for late broods.

Loafing Site Requirements

Loafing sites are important to broods. Best loafing sites are small, yet large enough for the birds to get out of the water to sun and preen themselves. These sites are surrounded by water, allow good visibility and are at the edge of cover.

Such sites should be about 18 by 18 inches or larger in area and 2 to 6 inches above water. About 10 to 20 loafing sites per acre in the form of small islands, muskrat mounds, stumps, logs and tussocks should be scattered throughout the habitat. In some cases, relatively bare points of land and shorelines offer marginal substitutes for more desirable types of loafing sites.

Brood Habitat on Impoundments - A Case Study

According to a survey of wood duck use of impoundments in Maryland, it was found that:

(1) very few impoundments received the majority of the brood use, and

(2) several nesting units were not used by broods. The key to heavy use of certain impoundments is a heavy abundance of brood cover in early spring.

As many of the broods hatch in May, seasonal plant growth in Ontario has not usually proceeded far enough at this time to provide essential brood cover. The cover in heavily-used impoundments consists of dead and downed timber and various swamp shrubs.

The heavily-used Maryland impoundments were developed by constructing dikes and impounding areas of low-quality timber and swamp shrubs.

One unit seemed to provide optimum habitat for wood ducks with up to 7 ducks per acre reared to flight age. Water depth was found to average 17 inches, with a maximum of 37 inches. Water is held to full pool level the year round.

There is a rather sharp drop-off in topography, with the higher 40% of the unit supporting live or partially live trees, shrubs and emergent aquatics. The lower 60% of the unit consists of dead and downed timber with open water or floating vegetation. The shallow water part averages 7 inches in depth, and the deep portion 23 inches. Duck meal, slender pondweed *(Potamogeton pusillus)* and watershield

(Brasenia schreberi) are the only common plant species in the deeper portion of the unit. In the shallow parts, marsh plants include sweet pepperbush, sweetbells, winterberry, sedges *(Carex Spp.)*, rice cutgrass *(Leersia oryzoides)*, three-way sedge *(Dulichium arundinaceum)*, soft rush, and water purslane *(Ludvigia palustris)*. A pH of 5 to 8, total alkalinity of 12 to 50 ppm, and total nitrates up to 1.4 ppm occurred. Much of the water draining into this unit came off fields which were heavily limed and fertilized. The runoff increased fertility and made it higher than normal for such an acid site.

Over most of the wood duck's breeding range similar impoundments of 10 to 20 acres or larger could be constructed. An integrated system of artificial nest box placement and the creation of adequate brooding habitat would materially increase wood duck populations over much of southern Ontario.

Methods of Population Dispersion

Wood duck populations are generally quite localized in southern Ontario. An exceptional situation on the Rideau River in eastern Ontario exists, however, where continuous habitat is found along the river's edge for miles. Breeding birds tend to be found only in those pockets of habitat that are suitable for completing a life cycle. Often breeding and brooding habitat are present, but a lack of nesting cavities creates a limiting factor.

In many cases, present habitat needs only elementary management to make it preferred for wood ducks. Much of the flooded bottomland swamps and meandering streams in Ontario can be made suitable with a very small degree of effort involved. Breeding birds seeking nesting habitat will not normally wander far from the areas in which they were hatched and raised. Only in years when water levels are not normal or when large surpluses of breeders occur, pairs wander long distances to seek new habitat.

For these reasons, it is necessary to create new habitat in close proximity to areas where birds already breed. Good man-made habitat has often lacked wood ducks for years until abnormal conditions forced breeders out of their ancestral areas into new regions.

Owing to their reliance on water conditions and special habitat requirements, wood ducks do not usually produce large surpluses in unmanaged habitat. For this reason, it is necessary to provide optimum conditions in core areas to induce surplus breeders to pioneer newly created habitat. Nest boxes should be placed in clusters on good

breeding and brooding sites to build wood duck numbers. Improvements should then radiate from these managed central core areas to supply excess breeders for new habitats.

Nest Boxes

Nest boxes, properly placed in good breeding habitat, predator-proofed and maintained regularly can produce many more wood ducks per acre than natural cavities.

Box Requirements

A well-built box should last 25 years or longer if made of cypress lumber, 26-gauge galvanized sheet metal, or aluminum. If it is desirable to erect less durable boxes (5 years or less), rough-cut pine or spruce lumber is satisfactory. Western red or eastern white cedars will last for 8 - 10 years.

Boxes should be inspected each winter and repairs made. If annual maintenance is not possible, inspection should be made at least every third year. The less durable the material, the more often inspection is required.

When a nest box program is started, acceptance of wood ducks is generally greater in wooden than in metal boxes. Likewise, vertical boxes may receive greater acceptance than horizontal ones. Initially it may be important to provide vertical wooden boxes, then graduate to the more durable metal types.

Figure 1 illustrates an up-to-date design that is quite starling-proof and easily constructed. This particular box probably represents an ideal form and should be adopted over older types where feasible. Once a population begins to use artificial structures, the type of box seems to make little or no difference, and other more durable or more predator-proof materials can be used. Metal boxes do not, as once

thought, lower hatching success or increase desertion.

If predator-proofing in the form of metal cones, sandwiched aluminum sheets, or aluminum down-spouting is integrated into the vertical structure, a 4-inch diameter circular hole is preferable. Horizontal structures with a 4x11-inch or 5x11-inch hole will discourage starling nesting.

As wood ducks do not carry nesting material, it must be provided for them. A sawdust-wood shaving mixture seems to be best. Nesting material should be provided to a depth of 3 to 5 inches. A 5-inch layer in the bottom of horizontal boxes with a shallow depression formed near the back of the box encourages hens to nest in the most psychologically secure portion of the structure.

Young wood ducks leave the nest by a progressive series of upward leaps before they are 24 hours old. The interior of the box must therefore contain toeholds permitting them to cling to the inside of the box before the entrance is gained. Constructing boxes of rough lumber will provide such sites, but metal and plywood structures require screen or hardware cloth strip, 4 inches or more wide, extending to the entrance from the nest basin.

Mounting, Protection and Placement of Boxes

Where feasible, posts are the most suitable mounts for boxes, because they are easier to predator-proof and can be placed where desired. It may be better to mount boxes on trees under certain situations, including

1. Extreme water fluctuations (3 feet or more)
2. Depth of water too great
3. A very soft, unstable bottom
4. Extreme ice movement
5. Economy

When mounting boxes on metal posts, the bottom type must be considered. If the pond bottom is moderately firm, an 8 foot post driven about 2 feet into the soil is adequate. If the bottom is deeper and soft, one post can be driven into the bottom with only 2 to 3 feet projecting above the water surface. A second post is bolted on with sufficient overlap to provide strength and height.

The best height for boxes is 4 to 5 feet above the high water mark where boxes are on posts over water. In upland woods, heights of around 45 feet seem to have the greatest use. Boxes will be used if hung as low as 15 feet. The direction of the entrance is immaterial as long as it is easily visible to the ducks.

A nest box program must not be attempted unless boxes are adequately predator-proofed. An effective guard for large trees is a metal band 50 inches wide.

Boxes should be erected in clusters of five to ten, spaced at 50- to 100-foot intervals within clusters. If possible, they should be placed over water within or adjacent to suitable brood cover. When initiating a program, it is important that the boxes be quite visible to the ducks. They should *not* be placed in thick stands of trees or beneath shrub growth.

It is best to start with a few boxes and add to them as they are accepted. Begin with five to ten, for example, and provide more when use reaches 30-50%. Do not put up more boxes than can be maintained.

Habitat Management on Impoundments

Low-grade acid swamps and boggy areas can quite often be converted into good wood duck habitat by strategic placement of a modest water control structure. It should be noted that all water control devices used to create wood duck areas should be of the stop-log or dropboard type, to permit complete periodic drawdowns.

To manage wildlife effectively it is necessary to manipulate vegetation to the desired successional stage. The primary successional stages of aquatic growth best utilized by woodies are most easily created by the manipulation of water levels.

Just as an open field gradually changes its vegetational composition until one day it reaches a climax stage of mixed deciduous forest, the aquatic vegetation of a marsh or pond changes and decomposes until eventually the marsh fills and is covered with trees. The early successional stages of submergent vegetation are the forms most usable by wood ducks, therefore succession must be set back by periodic water drawdowns.

But the picture is somewhat more clouded because of certain chemical changes which take place in an impoundment when vegetation dies and starts decomposing. Especially in acidic sites where much submerged woody material exists (as in high-grade wood duck habitat), high levels of soluble iron and manganese compounds form which act as vegetation inhibitors.

Only acid-tolerant plants survive under such conditions, but these

are of small value to waterfowl. Snails and other invertebrates are unable to accumulate sufficient calcium and phosphorus to build their shells and ectoskeletons, with a resultant lack of these valuable food items for young ducklings. Breeding birds and broods will reject marshes with a dearth of animal foods and select those with a wealth of small crustaceans and other animal life.

One of the most inexpensive and promising techniques for rejuvenating "stale" marshes is a well-planned periodic drainage of the marsh area so that soil aeration will occur. Manganese and iron compounds will become insoluble by aeration and other essential nutrients will be released from decaying over-mature vegetational stages.

Probably the best indicator of a marsh's lowered productivity is the increase in soluble iron. If soil tests indicate an iron concentration of over 100 ppm, drainage is a necessity. Samplings should be taken in July or August, and provisions must be made to treat samples quickly to prevent change before analysis. After it has been determined that a drawdown is needed, a specific procedure must be followed.

Drainage should occur in the late fall to expose at least 75% of the area bottom. Nutrient losses will be smallest when water levels are dropped just before ice forms a permanent winter cover. Water should be withheld from the marsh during winter and spring into the summer until the concentration of dissolved iron has fallen to less than 20 ppm. If water levels are then renewed, little is accomplished except to temporarily correct the problem.

Iron concentrations of over 100 ppm may recur within 2-8 years,

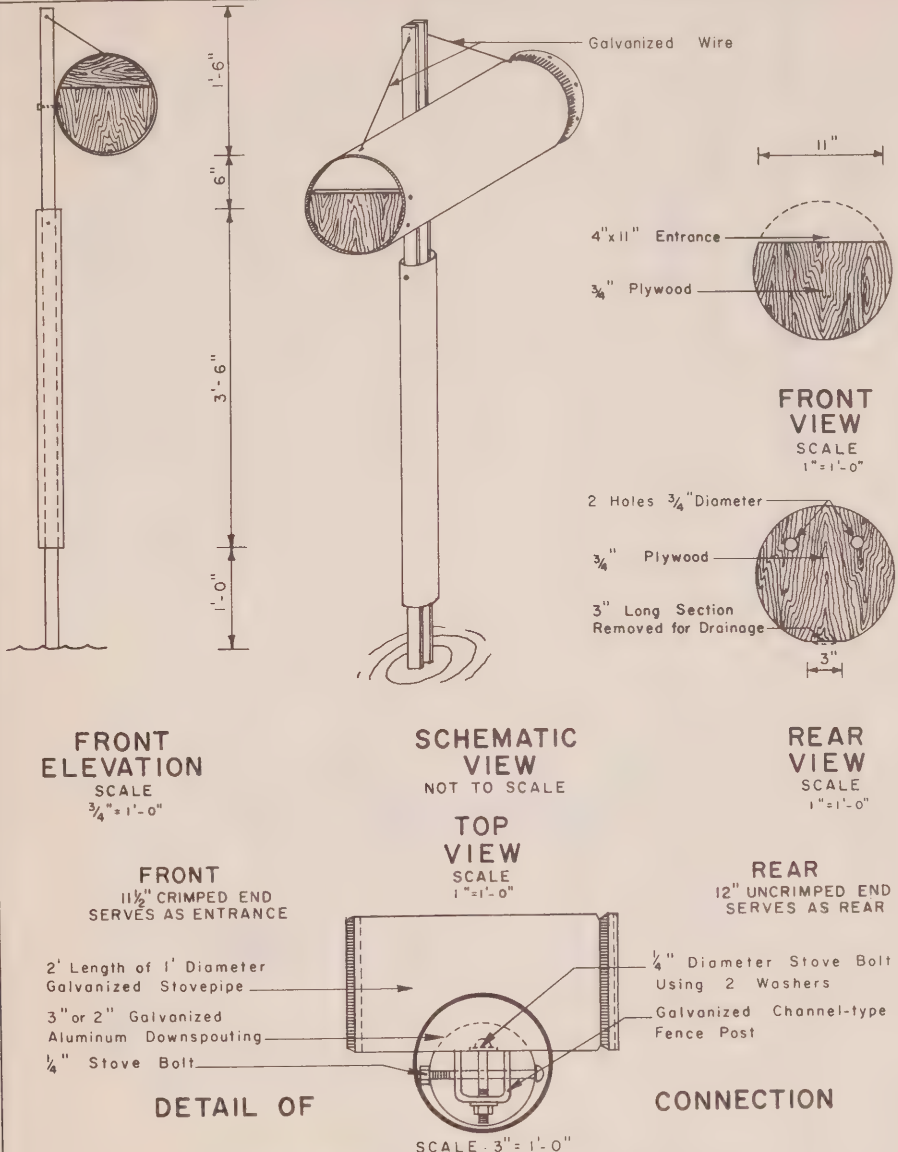
requiring another drawdown. Long-range correction of the problem is accomplished by liming the soil with ground limestone until a pH of at least 7.5 is reached. There seems to be little danger from applying too much lime, but it is possible to add too little, as the soil reaction may be raised to pH 6.5 - the optimum for bringing iron back into solution. In determining lime requirements for a marsh, the reaction of the dried and aerated soil should be used in the calculation.

The costs of liming soils are high, and often the procedure is not feasible because the area is not accessible to equipment. Where liming is not possible, a program of late fall drawdowns should be adhered to based on soluble iron concentrations, but over the long term application of limestone is one of the cheapest methods of providing top quality waterfowl breeding and brooding habitat. Without control over water quality and plant succession on impoundments the value of wood duck boxes is lessened considerably.

Optimum Habitat Requirements		
	Breeding Habitat	Brooding Habitat
Water		
Depth	3 to 18 inches over 75% of area	0 to 1 foot - 25% of area 1 to 3 feet - 50% of area 3 to 6 feet - 25% of area
	Occurrence from mid-April...	until mid-September
Flow	3 mph or less, with abundant backwaters	less than 1 mph
Cover		
Water: Cover ratio	50:50	25:75
Type	flooded trees, shrubs and emergents or combinations	flooded trees, shrubs and emergents or combinations
Over-head height	about 2 feet above water	1 to 2 feet above water
Loafing Sites		
Number	not known-tree limbs used in woodland habitat	10 to 20 per acre
Size	not critical	18 by 18 inches or larger
Height above water	not critical	2 to 6 inches for pre-flight broods
Optimum Densities	1 pair per 20 acres - natural cavities 2 pairs per acre - artificial cavities	2 to 5 flying young per acre

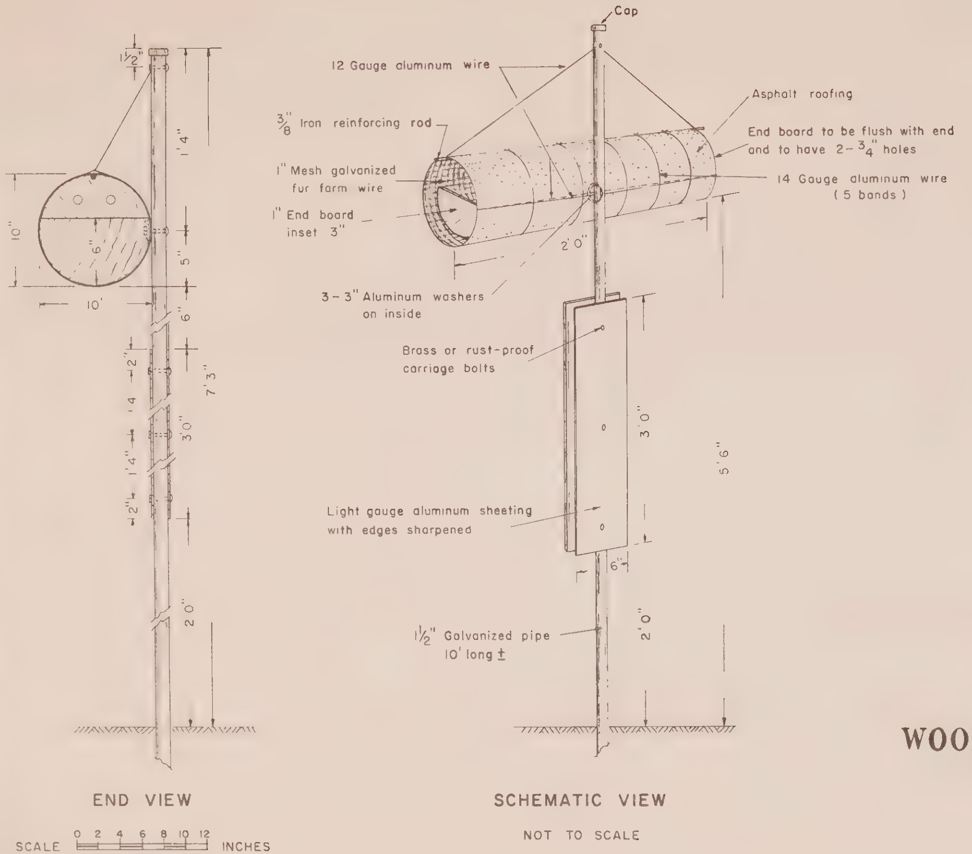
Natural Cavity Criteria		
	Optimum	Acceptable
Height	20 to 50 feet	6 feet and up
Entrance Size	4 inches in diameter	3½ to 12 inches in diameter
Cavity Bottom	10 by 10 inches or 11 inches in diameter	8 to 15 inches in diameter
Depth of Cavity	24 inches	6 to 48 inches
Tree sizes	24 to 36 inches d.b.h.	more than 16 inches d.b.h.
Density	more than 1 usable cavity per 5 acres of timber	1 usable cavity per 5 acres of timber
Distance to water	less than ½ mile	½ mile

Artificial Cavity Criteria		
	Vertical type	Horizontal type
Length	24 inches	24 inches
Diameter of cavity	11 inches or 10 by 10 inches square	12 inches
Entrance size (predator-proof)	4 inches diameter	5 by 11 inches
Entrance size (not predator-proof)	3 by 4 inches 3 vertical, 4 horizontal	same as for vertical type



CONSTRUCTION DETAILS FOR STARLING PROOF WOOD DUCK BOX

FIGURE 1



PROPOSED
ALTERNATIVE DESIGN
FOR
WOOD DUCK NESTING BOXES

SCALES AS SHOWN

FIG. 3

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STUDENT'S RESOURCE KIT ON THE ENVIRONMENT

1. This kit is intended as a source of information on environmental conservation and students should be encouraged to have recourse to it before writing letters to Government agencies.

2. Copies of individual papers contained in this kit are available to students at no cost upon request to the address on the back cover of each paper.

3. Upon written request by the Principal, bulk supplies are available at no cost to teachers who may wish to use certain papers as classroom teaching aids.

4. As subject notes are updated or new notes published, copies will automatically be supplied. Please ensure that old notes are removed and their replacements inserted.

5. The Department offers professional guidance and assistance to teachers interested in environmental conservation subjects.

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